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Energy Optimization Assessment at U.S. Army Installations

West Point Military Academy, NY

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Abstract: An Energy Optimization Assessment was conducted at West Point, NY, as a part of the International Energy Agency (IEA) Energy Conservation in Buildings and Community Systems (ECBCS) initiative to identify energy inefficiencies and wastes and propose energy-related projects with applicable funding and execution methods that could enable the installation to better meet the energy reduction requirements mandated by Executive Order 13123 and Energy Policy Act (EPAct) 2005. The study was conducted by the Energy Team, composed of the Construction Engineering Research Laboratory (ERDC-CERL) researchers and their subject matter experts, and the Pacific Northwest National Laboratory (PNNL). The scope of the Annex 46 Energy Optimization Assessment included a Level I study of the central energy plants and associated steam distribution systems providing heat to representative administrative buildings, laundry, dining facilities and other buildings and an analysis of their building envelopes, ventilation air systems, and lighting. The study identified 263 different energy conservation measures (ECMs) that would reduce West Point's annual energy use by up to 225,000 MMBtu/yr, or 25 percent. Most of the proposed energy conservation measures were quantified economically. These ECMs are presented in eight packages with recommendations on their implementation strategies.

Executive Summary

This work conducted an Energy Optimization Assessment at West Point military academy as a part of the International Energy Agency (IEA) Energy Conservation in Buildings and Community Systems (ECBCS) initiative to identify energy inefficiencies and wastes and to propose energy-related projects with applicable funding and execution methods that could enable the installation to better meet the energy reduction requirements mandated by Executive Order 13123 and Energy Policy Act (EPAct) 2005.

A team of researchers from the Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL), the Pacific Northwest National Laboratory (PNNL) and Subject Matter Experts (SMEs) conducted the study, which was limited to a "Level I" assessment. They assessed and analyzed building envelopes, ventilation air systems, controls, interior and exterior lighting, and evaluated opportunities to use renewable energy resources.

The study identified a total of 281 potential energy conservation measures (ECMs) in nine categories: (1) Building Envelope, (2) Central Energy Plants, (3) Hot Water Heaters, (4) Renewables and Water, (5) Controls, (6) Dining Facilities, (7) Lighting, (8) Electrical, and (9) Heating, Ventilating, and Air-Conditioning (HVAC) (Table ES1); and economically quantified 275 ECMs (Appendix A).

Forty-three of these ECMs are a result of subject matter expert (SME) analyses, which included a survey of the particular building that each ECM applies to. The other 238 ECMs are a result of modeling the installation's energy use using the Facility Energy Decision System (FEDS) tool. Because the FEDS analysis does not involve a visit to each building for which an ECM is proposed, the analysis is not as thorough as the SME ECMs.

If all these ECMs were implemented, they would result in approximately \$18.6 million/yr in savings: 92,824 MWh/yr in electrical energy use; reduced electrical demand of 11,712 kilowatt (kW); 427,230 MMBtu/yr in thermal (mostly natural gas); and \$1.1 million/yr in maintenance. Implementing these projects would require an investment of \$58.3 million and will yield an average simple payback of 3.1 yrs.

Table ES1. Summary of nine energy conservation measure (ECM) groups.

ECM Category	Report Chapter	Electrical Savings			Thermal MMBtu/yr	$/yr	Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr						
Building envelope	3	4,299,124	4,697	$698,256	223,388	$2,917,246	$0	$3,615,502	$17,859,735	4.9
Central energy plant	4	56,841,394	4,695	7,162,741	89,287	813,368	518,879	8,494,988	33,727,949	4.0
Hot water heaters	11	2,054,135	246	$243,978	7,448	$107,520	–$291	$351,207	$326,495	0.9
Renewables & water	10	–10,000	0	–$1,250	2,700	$33,453	$0	$67,993	$385,000	5.7
Controls	5	1,185,000	0	$148,125	21,726	$269,185	$0	$417,310	$315,500	0.8
Dining facilities	6	137,000	0	$17,125	4,214	$52,211	$0	$69,336	$124,600	1.8
Lighting	9	10,589,479	1,979	$1,308,971	(17,476)	($241,324)	$522,560	$1,590,207	$3,368,892	2.1
Electrical	7	600,270	0	$75,034	0	$0	$0	$75,034	$3,150	0.0
HVAC	8	17,127,711	95	$2,144,516	95,943	$1,279,420	$10,646	$3,934,582	$2,205,394	0.6
Total		***92,824,112***	***11,712***	***$11,797,496***	***427,230***	***$5,231,080***	***$1,051,794***	***$18,616,159***	***$58,316,715***	***3.1***

Note that the FEDS ECMs were further divided into subsets of ECMs that are fully described in Chapters 3 through 11 (as indicated in the tables following each ECM group description). ECM summaries resulting from FEDS analysis are indicated by an asterisk in Tables ES2 through ES10.

The **Building Envelope** category consists of 72 ECMs (summarized in Table ES2). BE #5 through BE #9 summarize ECMs for groups of buildings that resulted from a FEDS analysis and that can be broken into smaller projects as indicated in Sections 3.5 through 3.9. If all Building Envelope ECMs were implemented, they would save 4,299 MWh/yr; 4,697 KW in Demand; and 223,388 MMBtu/yr in thermal savings, resulting in a total savings of $3.6 million/yr. The investment cost of $17.9 million results in a simple payback of 4.9 yrs.

The **Central Energy Plant (CEP)** category consists of nine ECMs (summarized in Table ES3). If all CEP ECMs were implemented, they would save 1,185 MWh/yr; 21,727 MMBtu/yr in thermal savings; resulting in a total savings of $417K/yr. The investment cost of $316K results in a simple payback of 0.8 yrs.

Table ES4 summarizes 38 **Hot Water Heater Insulation** ECMs identified by FEDS. Chapter 5 includes detailed descriptions. These could save 2,054 MWh/yr electrical use; reduce peak electrical demand by 246KW; and generate 7,448 MMBTU in thermal savings for a total savings of $351K/yr resulting in a simple payback of 0.9 yrs.

Table ES5 summarizes one **Renewable** and one **Water** ECM. Shower water heat recovery would save 2,700 MMBTU/yr* for a savings of $33K/yr. The investment cost of $245K results in a simple payback of 7.3 yrs. Fixing leaks in 15 cooling towers and installing a common condensing unit in Taylor Hall would save 19 million gal of water/yr, or $35K/yr. The investment of $140K results in a payback of 4.1 yrs.

* 1 MMBTU = 1 thousand thousand BTUs

Table ES2. Summary of building envelope ECMs.

ECM #	ECM Description	Electrical Savings			Thermal MMBtu/yr	$/yr	Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint ($/yr)	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr						
BE #1	Establish a cool roof strategy	831,800	0	$103,975	−1060	−13133	$—	$90,842	$—	0.0
BE #2	Add insulated panels behind single pane windows, Gillis field house Building 633	0	0	$—	24	297	$—	$297	$700	2.4
BE #3	Install interior windows in Building 622 (library) and in the basement of Building 685	0	0	$—	0	0	$—	$—	$—	-
BE #4	Insulate attic in southern part of Building 622	0	0	$—	376	4655	$—	$4,655	$50,500	10.8
BE_5*	Attic ceiling: increase insulation by R−13 (blow−in cellulose)	4,689	103	$2,640	8053	104264	$—	$106,904	$470,233	4.4
BE 6*	Add insulation to interior surface of metal roof: 4-in. fiberglass	789,827	1,383	$140,716	45944	618225	$—	$758,941	$1,762,796	2.3
BE 7*	Insulate roof	2,079,632	2,113	$336,224	92297	1166259	$—	$1,502,483	$3,494,383	2.3
BE 8*	Insulate wall	118,694	189	$19,999	16300	221322	$—	$241,321	$2,995,075	12.4
BE 9*	Install thermal break or double pane window	474,482	909	$94,702	61454	815357	$—	$910,059	$9,086,048	10.0
Totals		*4,299,124*	*4,697*	*698,256*	*223,388*	*2,917,246*	*0*	*3,615,502*	*17,859,735*	*4.9*

Table ES3. Summary of central energy plant ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
CEP #1	Install missing insulation in CEP and heat distribution, repair leaks	0	0	$–	0	$–	$–	$–	$–	–
CEP #2	Gas metering for main CEP In Building 604	0	0	$–	40,000	$495,600	$–	$495,600	$69,384	0.1
CEP #3	Small boiler in CEP Building 845 (laundry boiler)	0	0	$–	22,680	$281,005	$–	$281,005	$800,850	2.8
CEP #4	Reduce steam pressure to a standardized mid or low pressure	0	0	$–	3,600	$44,604	$3,000	$47,604	$310,000	6.5
CEP #5	Longer use of the backpressure steam turbine by increasing the low pressure steam demand	1,200,000	0	$150,000	0	$–	$–	$150,000	$240,000	1.6
CEP #6	Interconnect the north and the central heating distribution system	0	0	$–	22,680	$281,005	$–	$281,005	$200,000	0.7
CEP #7	Hot water conversion and replacement of the unstable tunnels	0	0	$–	7,200	$89,208	$240,000	$329,208	$700,000	2.1
CEP #8	Trigen Plant In CEP 604	55,957,440	5,000	$7,042,747	–296,000	$(3,667,440)	$–	$3,375,307	$28,200,000	8.4
CEP #9*	Abandon CEP 604 and install heating and hot water systems in buildings	–316,046	–305	$(30,006)	289,127	$3,289,386	$275,879	$3,535,259	$3,207,715	0.9
Totals		*56,841,394*	*4,695*	*$7,162,741*	*89,287*	*$813,368*	*$518,879*	*$8,494,988*	*$33,727,949*	*4.0*

Table ES4. Summary of hot water ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint	Investment	Simple Payback
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr	$/yr	$/yr	$	yrs
SHW #1*	Replace existing water heaters	1,033,369	107	$121,742	4308	$67,499	$(291)	$188,950	$209,693	1.1
SHW #2*	Wrap hot water tank with insulation	1,020,767	139	$122,236	3140	$40,021	0	$162,257	$116,802	0.7
Totals		*2,054,135*	*246*	*243,978*	*7,448*	*107,520*	*–291*	*351,207*	*326,495*	*0.9*

Table ES5. Summary of renewable and water conservation ECMs.

ECM #	ECM Description	Electrical Savings KWh/yr	Electrical Savings kW Demand	Electrical Savings $/yr	Thermal MMBtu/yr	Thermal $/yr	Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
REN #1	Barracks shower hot water heat recovery	0	0	$—	2700	$33,453	$—	$33,453	$245,000	7.3
WATER #1	Fix cooling tower leaks	(10,000)	0	$(1,250)	0	$—	$—	$34,540	$140,000	4.1
Totals		*(10,000)*	*0*	*$(1,250)*	*2700*	*$33,453*	*$—*	*$67,993*	*$385,000*	*5.7*

The **Controls** category consists of nine ECMs (summarized in Table ES6). If all Controls ECMs were implemented, they would save 1,185 MWh/yr and 21,726 MMBtu/yr in thermal savings resulting in a total savings of $417K/yr. The investment cost of $316K results in a simple payback of 0.8 yrs.

The **Dining** ECM group consists of three ECMs (summarized in Table ES7). If all were implemented, they would save 600 MWh/yr, resulting in savings of $75K/yr. The investment cost of $3,150 results in a simple payback of 1.8 yrs.

Table ES8 summarizes the 103 **Lighting** ECMs. LI #5 through LI #10 are summaries of ECMs for groups of buildings that resulted from a FEDS analysis, and that can be broken into smaller projects as indicated in Sections 9.5 through 9.10. If all were implemented, they would save 10.6 million MWh/yr; reduce peak electrical demand by 1,979 KW; have a 17,476 MMBtu/yr thermal penalty; and reduce maintenance costs by $523K/yr resulting in total savings of $1.6 million/yr. The investment cost of $3.4 million results in a simple payback of 2.1 yrs.

The **Electrical** ECM group consists of two ECMs as listed in Table ES9. If implemented, they would save 600 MWh/yr or $75K/yr. The investment cost of $3,150 results in a simple payback of 0.04 yrs.

Table ES10 lists the 42 **HVAC** ECMs. HVAC #10 through HVAC #14 summarize ECMs for groups of buildings that resulted from a FEDS analysis and that can be broken into smaller projects as indicated in Sections 8.10 through 8.15. If all HVAC ECMs were implemented, they would save 17,128 MWh/yr; 95KW in electrical demand; 95,943 MMBtu/yr in thermal savings, and $11K in maintenance savings resulting in a total savings of $3.9 million/yr. The investment cost of $2.2 million results in a simple payback of 0.6 yrs.

The Level I analyses of multiple complex systems conducted during the Energy Optimization Assessment are not intended to be (nor should they be) precise. The quantity and quality of the systems improvements identified suggests that significant potential exists.

Table ES6. Summary of controls ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
CON #1	Increase /decrease space temperature setpoints and make them uniform	0	0	$–	0	$–	$–	$–	$–	–
CON #2	Reduce HVAC run time /schedule air handling units (AHUs) to match building occupancy	86,000	0	$10,750	1,233	$15,277	$–	$26,027	$20,000	0.8
CON #3	Improved temperature control in Kitchen, Building 745	25,500	0	$3,188	383	$4,745	$–	$7,933	$5,000	0.6
CON #4	Keller Army Hospital AHUs retrofit and controls	772,000	0	$96,500	16,800	$208,152	$–	$304,652	$200,000	0.7
CON #5	Control motor VFDs instead of full constant speed and replace malfunctioning VFDs	105,000	0	$13,125	0	$–	$–	$13,125	$5,000	0.4
CON #6	Remove pneumatic thermostats from spaces with direct digital control (DDC) controls	6,500	0	$813	0	$–	$–	$813	$500	0.6
CON #7	Connect more mechanical equipment to Energy Management Control System (EMCS)	0	0	$–	0	$–	$–	$–	$–	–
CON #8	Initiate night/weekend and summer/winter setpoint changes	0	0	$–	0	$–	$–	$–	$–	–
CON #9	Fix failed controls in the Post Exchange (PX) and Building 1204	190,000	0	$23,750	3,310	$41,011	$–	$64,761	$85,000	1.3
Totals		*1,185,000*	*0*	*$148,125*	*21,726*	*$269,185*	*$–*	*$417,310*	*$315,500*	*0.8*

Table ES7. Summary of dining facility ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
DIN #1	Modify kitchen hoods with end skirts, Bldg 745	95,200	0	$11,900	1,114	$13,802	$–	$25,702	$19,600	0.8
DIN #2	Repair freezer door sears, Bldg 745	41,800	0	$5,225	0	$–	$–	$5,225	$20,000	3.8
DIN #3	Heat recovery from refrigeration machines, Bldg 745	0	0	$–	3,100	$38,409	$–	$38,409	$85,000	2.2
Totals		*137,000*	*0*	*$17,125*	*4,214*	*$52,211*	$–	*$69,336*	*$124,600*	*1.8*

Table ES8. Summary of lighting ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
LI #1	Use occupancy sensors to shut off lights, Buildings 663, 714 727 & various barracks	363,886	0	$45,486	0	$–	$–	$45,486	$48,900	1.1
LI #2	Shut off exterior lights during daytime	38,300	0	$4,788	0	$–	$–	$4,788	$1,000	0.2
LI #3	Shut off interior lights during daytime in areas that are bright from daylight	6,000	0	$750	0	$–	$–	$750	$1,000	1.3
LI #4	Replace incandescent lights with Compact Fluorescent Lamp (CFL) (Bldgs 685, 622, 714)	34,000	0	$4,250	0	$–	$–	$4,250	$2,000	0.5
LI #5*	Replace existing exit signs with electroluminescent exit signs	6,076,536	1,224	$742,468	–11470	$(163,336)	273776	$852,908	$433,588	0.5
LI #6*	Replace existing exit signs with electroluminescent exit signs	1,701,571	229	$205,340	–2828	$(37,828)	144814	$312,326	$430,802	1.4
LI #7*	Replace T8 lighting with Super T8 lighting	884,782	205	$115,221	–796	$(9,850)	24808	$130,179	$1,155,946	8.9
LI #8*	Replace Metal Halide (MH) with high efficient electronic ballast MH lighting	189,617	49	$24,936	–149	$(1,842)	9144	$32,238	$263,543	8.2
LI #9*	Replace T12 with Super T8 lighting	1,259,913	265	$161,229	–2209	$(28,171)	64728	$197,786	$994,250	5.0
LI #10*	Replace metal halide high–bay lighting with T5 lighting	34,875	7	$4,504	–24	$(297)	$5,290	$9,497	$37,863	4.0
Totals		*10,589,479*	*1,979*	*$1,308,971*	*–17,476*	*$(241,324)*	*$522,560*	*$1,590,207*	*$3,368,892*	*2.1*

Table ES9. Summary of electrical ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Plant Energy Savings		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr	MMBtu/yr	$/yr				
EL #1	Use energy efficient electric motors; Bldgs 750, 5102, 5440, 6901	17,350	0	$2,169	0	$–	0	$–	$–	$2,169	$3,150	1.5
EL #2	Switch off computers when not in use	582,920	0	$72,865	0	$–	0	$–	$–	$72,865	$–	0.0
Totals		*600,270*	*0*	*$75,034*	*0*	*$–*	*0*	*$–*	*$–*	*$75,034*	*$3,150*	*0.04*

Table ES10. Summary of HVAC ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Plant Energy Savings		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr	MMBtu/yr	$/yr				
HVAC #1	Glycol heat recovery change	0	0	$–	682	$8,450	$–	$–	$–	$8,450	$5,000	0.6
HVAC #2	Heat recovery from computer room air-conditioning	0	0	$–	2,047	$25,362	$–	$–	$–	$25,362	$50,000	2.0
HVAC #3A*	New solutions for re-heat condenser heat, Bldg 655	1,135,000	0	$141,875	2,867	$35,522	$–	$–	$–	$177,397	$323,000	1.8
HVAC #3B*	New solutions for re-heat heat exchanger, Bldg 655	1,128,200	0	$141,025	2,867	$35,522	$–	$–	$–	$176,547	$483,000	2.7
HVAC #3C*	New solutions for re-heat bypass cooling coil, Bldg 655	1,135,000	0	$141,875	2,867	$35,522	$–	$–	$–	$177,397	$317,000	1.8
HVAC #4	Re-commissioning of HVAC systems and controls	15,750,000	0	$1,968,750	70,313	$871,172	$–	$–	$–	$2,839,922	$160,000	0.1
HVAC #5	Use existing steam absorption chiller and supplement with small electric chiller at hospital	0	0	$–	0	$–	$–	$–	$–	$–	$(300,000)	-
HVAC #6	Switch off boilers in Holleder Center; use local gas burners to regenerate desiccant wheel in de-humidifier	64,500	0	$8,063	900	$11,151	$–	$–	$–	$19,214	$10,000	0.5

ECM #	ECM Description	Electrical Savings			Thermal		Plant Energy Savings		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr	MMBtu/yr	$/yr				
HVAC #7	Use waste heat from ice makers / use condenser heat in the Holleder Building to pre–heat outdoor air	0	0	$–	0	$–	$–	$–	$–	$–	$–	–
HVAC #8	Do not replace AHUs at the Keller Army Hospital	0	0	$–	0	$–	$–	$–	$–	$500,000	$500,000	1.0
HVAC #9	Install CO_2 controls In the Keller Army Hospital	56,000	0	$7,000	6,100	$75,579	$–	$–	$–	$82,579	$100,000	1.2
HVAC 10*	Replace boiler with more efficient one	293	0	$27	3,527	$94,948	$–	$–	$2,879	$97,854	$404,626	4.1
HVAC 11*	Install infrared heating	–6,448	0	$(687)	5,121	$100,491	$–	$–	$8,582	$108,386	$365,931	22.2
HVAC 12*	Replace existing furnace with condensing liquid petroleum gas (LPG) furnace – 92% efficient	–43,668	0	$(4,937)	3,625	$47,071	$–	$–	$(1,726)	$40,408	$311,786	7.7
HVAC 13*	Add automatic electric damper to existing boilers	0	0	$–	761	$9,674	$–	$–	$(175)	$9,499	$8,740	0.9
HVAC 14*	Replace cooling equipment	172,033	95	$24,425	0	$–	$–	$–	$1,086	$25,511	$266,311	10.4
Totals		*17,127,711*	*95*	*$2,144,516*	*95,943*	*$1,279,420*	*$–*	*$–*	*$10,646*	*$3,934,582*	*$2,205,394*	*0.6*

*Assumes Option A

Recommendations

Because many potential ECMs were found, they were grouped to emphasize recommended implementation approaches. The first approach involved ECMs that have very little or no additional investment such as the cool roof strategy, which simply requires a change in policy regarding allowed roofing materials. Projects that require small investments (defined here as investments of $10K or less) were grouped together. Recommissioning of HVAC systems was identified as a separate group because of its wide applicability and typically quick payback. Projects recommended because of their simple payback potential of less than 6 yrs were grouped into those having a modest investment of $10K to $200K and those requiring greater than $200k investment. Several projects require a more detailed Level II analysis, such as those involving the central energy plants. Finally, ECMs were sorted and filtered to show those with the largest impact on maintenance costs.

Policy Related and Low Cost Measures

The following measures require virtually no additional capital investment. These low cost/low-risk (so-called “slam dunk”) measures can be implemented quickly and should be funded internally as soon as possible. While the estimated cost of establishing installation-wide setpoints is $100K, this could be implemented as part of the planned expansion of the installation wide building control system at virtually no additional cost:

- use a cool roof strategy
- establish an installation wide building temperature setpoint.

Low cost projects

Tables ES11 through ES14 summarize ECMs that require investments. Table ES11 lists 56 ECMs found to have an investment of $10K or less and result in a simple payback of less than 6 yrs. All 56 ECMs could be implemented as a group for a total of $169K, save $332K/yr, and result in a simple payback of just under 6 months. West Point should seek internal funding for these projects.

Re-commissioning

Although re-commissioning of HVAC systems was not economically analyzed, an aggressive re-commissioning of HVAC systems is recommended because numerous opportunities that typically have a very short payback period were noted throughout the installation. Since this also requires that the systems be periodically checked and maintained to retain the savings, it is recommended that West Point pursue this through third party financing such as an Energy Savings Performance Contract (ESPC).

Short payback and moderate investment projects

Table ES12 lists 124 ECMs with a simple payback of less than 10 yrs, but which require moderate investments of between $10K and $200K. These ECMs together would have annual savings of $5.9 million at a cost of $2.5 million for a simple payback of 0.4 yrs. Due to their size and complexity, some may need to be developed further by an Energy Optimization Assessment Level II effort.

Short payback and significant investment projects

Table ES13 lists 10 ECMs with a simple payback of less than 6 yrs, but also require significant investments of over $200K each. These ECMs would have annual savings of $6.6 million at a cost of $7.5 million for a simple payback of 1.1 yrs. Due to their size and complexity, most need to be developed further by an Energy Optimization Assessment Level II effort. It is recommended that West Point apply for funds from Installation Management Command's (IMCOM's) Utility Modernization program for these projects.

Level II analysis candidates

Some of the ripest opportunities for savings come from the moderate and high cost ECMs identified. These often require a combination of in-house and outside support.

It is recommended that West Point pursue Level II of this Energy Optimization Assessment for select central energy plant and HVAC ECMs:

- ECMs CEP #3, CEP #4 and CEP #5, CEP #6, CEP #7, CEP #8, CEP #9
- HVAC #3A through HVAC #3C.

CEP #3 involves the boiler in Bldg 845, which supplies the laundry facility and a few other buildings. Three possible solutions are described and a simple cost benefit analysis presented for one of the solutions. The Level II analysis is required to determine the optimum solution.

CEP #4 and CEP #5 involve the output of steam pressure of the CEP located in Bldg 604. One possibility is to standardize output at a lower steam pressure that can be used by all buildings served with the minimization of the need for pressure reducing valves. The optimal pressure has to be found in a more detailed study. It depends on the hydraulic situation and the demand of high and mid pressure steam in the buildings. Another possibility is to more fully use the two steam turbines to generate electricity. A more detailed study of the costs and savings is required to determine the best option and better understand the economics.

CEP #6 proposes the interconnection of the north and the central heating distribution systems. This would allow more fully loaded and therefore more efficient boiler operation. Further analysis is needed to analyze the complexities of interconnected boilers, distribution systems, and building loads.

CEP #7 requires a Level II analysis not for decisionmaking, rather to create a new design. The distribution tunnel system is such that it is unsafe and must be replaced regardless of energy use. The analysis would produce a design for a hot water system to replace the steam currently distributed.

CEP #8 and CEP #9 are related and would affect many of measures described in CEP #1 through CEP #7. The idea is to install, in CEP 604, a new gas turbine and a waste heat boiler. This boiler will generate steam to drive the existing back pressure turbine #2 in winter. This first part of the suggested measure is also described in "Energy Conservation Savings Measure" (ECSM) proposal from NORESCO in April 2005.

Recommendations for the scope of the Level II study can be based on the results of the Level I study and on the demonstration project results. A specific Level II scope will be jointly developed by the CERL and West Point teams through review and discussion of results documented in this Level I report. The Level II report will include an analysis that "guesses at

nothing – measures everything.” The results will be a set of demonstrated process and systems improvements based on hard numbers. CERL and expert consultants will provide guidance and further assistance to identify a specific Level II scope of work, respective roles, and the most expeditious implementation path. This will begin with a formal review of this (Level I) report, combined with a planning session to organize the Level II program.

Significant Maintenance Savings Projects

Table ES14 lists ECMs that offer the greates maintenance savings. It is recommended that West Point review these projects along with its maintenance program to determine the suitability of these ECMs as projects and or modification of maintenance contracts.

Table ES11. Summary ECMs requiring an investment < $10k and yielding a simple payback < 6 yrs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
BE #1	Establish a Cool Roofs Strategy	831,800	0	$103,975	−1,060	$(13,133)	$–	$90,842	$–	0.0
EL #2	Switch off Computers When Not In Use	582,920	0	$72,865	0	$–	$–	$72,865	$–	0.0
SHW_2C	Wrap Tank with Insulation	0	0	$–	14	$236	$–	$236	$16	0.1
LI #2	Shut Off Exterior Lights During Daytime	38,300	0	$4,788	0	$–	$–	$4,788	$1,000	0.2
SHW_2B	Install Faucet Aerators	8,792	3	$1,259	0	$–	$–	$1,259	$266	0.2
SHW_2A	Wrap Tank with Insulation, LFSHs	0	0	$–	106	$1,758	$–	$1,758	$448	0.3
LI_5I	Replace incandescent lights with CFL	143,605	32	$18,919	−86	$(1,069)	$5,122	$22,972	$7,267	0.3
LI_5A	Replace incandescent lights with CFL	3,224	1	$432	0	$–	$141	$573	$186	0.3
LI_5E	Replace incandescent lights with CFL	49,236	7	$5,980	−74	$(920)	$1,881	$6,941	$2,597	0.4
CON #5	Control Motor VFDs Instead Of Full Constant Speed and Replace Malfunctioning VFDs	105,000	0	$13,125	0	$–	$–	$13,125	$5,000	0.4
LI_5Z	Replace incandescent lights with CFL	12,895	3	$1,738	0	$–	$791	$2,529	$969	0.4
LI_5K	Replace incandescent lights with CFL	293	0	$57	0	$–	$22	$79	$31	0.4
LI_5AB	Replace incandescent lights with CFL	2,638	1	$354	−7	$(83)	$190	$461	$186	0.4
HVAC_13D	Add Automatic Electric Damper to Existing Boilers	0	0	$–	243	$3,014	$(26)	$2,988	$1,290	0.4
HVAC_13B	Add Automatic Electric Damper to Existing Boilers	0	0	$–	46	$569	$(5)	$564	$248	0.4
LI #4	Replace Incandescent Lights With CFL (Buildings 685, 622, 714)	34,000	0	$4,250	0	$–	$–	$4,250	$2,000	0.5
LI_5B	Replace incandescent lights with CFL	4,103	0	$474	0	$–	$175	$649	$340	0.5
LI_5AA	Replace incandescent lights with CFL	10,844	4	$1,469	−24	$(293)	$1,012	$2,188	$1,159	0.5
HVAC_13A	Add Automatic Electric Damper to Existing Boilers	0	0	$–	117	$1,449	$(15)	$1,434	$771	0.5
LI_5U	Replace incandescent lights with CFL	70,337	9	$8,211	−145	$(1,792)	$3,208	$9,627	$5,260	0.5
LI_5Y	Replace incandescent lights with CFL	4,982	1	$574	0	$–	$105	$679	$396	0.6
HVAC #1	Glycol heat recovery change	0	0	$–	682	$8,450	$–	$8,450	$5,000	0.6
CON #6	Remove Pneumatic Thermostats From Spaces With DDC Controls	6,500	0	$813	0	$–	$–	$813	$500	0.6
CON #3	Improved Temperature Control in Kitchen, Building 745	25,500	0	$3,188	383	$4,745	$–	$7,933	$5,000	0.6

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
HVAC_13F	Add Automatic Electric Damper to Existing Boilers	0	0	$–	4	$45	$(1)	$44	$31	0.7
LI_6R	Replace existing exit signs with electroluminescent exit signs	14,360	2	$1,737	−25	$(307)	$2,885	$4,315	$3,150	0.7
LI_6B	Replace existing exit signs with electroluminescent exit signs	35,169	1	$4,161	0	$–	$2,317	$6,478	$6,301	1.0
LI_6L	Replace existing exit signs with electroluminescent exit signs	4,689	1	$574	−7	$(82)	$290	$782	$788	1.0
LI_6M	Replace existing exit signs with electroluminescent exit signs	12,895	2	$1,557	−23	$(288)	$772	$2,041	$2,100	1.0
LI_6K	Replace existing exit signs with electroluminescent exit signs	31,066	4	$3,790	−30	$(378)	$2,124	$5,536	$5,776	1.0
LI_6N	Replace existing exit signs with electroluminescent exit signs	4,103	0	$490	−3	$(39)	$290	$741	$788	1.1
LI_6O	Replace existing exit signs with electroluminescent exit signs	55,390	6	$6,664	−77	$(1,405)	$3,476	$8,735	$9,451	1.1
HVAC_13C	Add Automatic Electric Damper to Existing Boilers	0	0	$–	229	$2,840	$(62)	$2,778	$3,095	1.1
LI_6C	Replace existing exit signs with electroluminescent exit signs	16,705	2	$1,986	−33	$(405)	$1,159	$2,740	$3,150	1.1
LI_6D	Replace existing exit signs with electroluminescent exit signs	16,705	2	$1,986	−33	$(405)	$1,159	$2,740	$3,150	1.1
SHW_1H	Replace existing water heaters with Condensing LPG Boiler – 91% Combustion Efficiency, Wrap Tank, Aerators	0	0	$–	190	$3,488	$3	$3,491	$4,099	1.2
LI #3	Shut off Interior Lights during Daytime in Areas that are Bright from Daylight	6,000	0	$750	0	$–	$–	$750	$1,000	1.3
LI_5F	Replace incandescent lights with CFL	38,392	17	$4,675	0	$–	$1,838	$6,513	$8,904	1.4
EL #1	Use Energy Efficient Electric Motors; Buildings 750, 5102, 5440, 6901	17,350	0	$2,169	0	$–	$–	$2,169	$3,150	1.5
HVAC_13G	Add Automatic Electric Damper to Existing Boilers	0	0	$–	41	$758	$(22)	$736	$1,121	1.5
LI_5L	Replace incandescent lights with CFL	586	0	$81	0	$–	$35	$116	$186	1.6
LI_5D	Replace incandescent lights with CFL	7,913	4	$974	0	$–	$279	$1,253	$2,087	1.7
SHW_1E	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank, Aerators	0	0	$–	147	$4,259	$(62)	$4,197	$7,526	1.8
LI_6W	Replace existing exit signs with electroluminescent exit signs	3,224	0	$382	0	$–	$481	$863	$1,575	1.8
LI_6V	Replace existing exit signs with electroluminescent exit signs	9,085	1	$1,090	−12	$(146)	$1,444	$2,388	$4,725	2.0
LI_6X	Replace existing exit signs with electroluminescent exit signs	7,913	1	$950	−19	$(233)	$1,444	$2,161	$4,725	2.2
HVAC_10I	Replace Existing Boiler with Conventional Gas Boiler – 84% Combustion Efficiency	0	0	$–	40	$2,373	$29	$2,402	$5,258	2.2
HVAC_13E	Add Automatic Electric Damper to Existing Boilers	0	0	$–	81	$999	$(44)	$955	$2,184	2.3

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
BE #2	Add Insulated Panels Behind Single Pane Windows, Gillis Field House Building 633	0	0	$–	24	$297	$–	$297	$700	2.4
LI_5X	Replace incandescent lights with CFL	4,689	1	$575	0	$–	$184	$759	$2,640	3.5
BE_5C	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–1,172	2	$(76)	83	$1,029	$–	$953	$4,295	4.5
BE_5B	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–293	2	$(19)	150	$1,855	$–	$1,836	$9,192	5.0
LI_9G	Replace T12 with Super T8 lighting	9,085	2	$1,077	–17	$(216)	$465	$1,326	$7,365	5.6
LI_9F	Replace T12 with Super T8 lighting	10,844	2	$1,280	–22	$(269)	$548	$1,559	$8,679	5.6
LI_9J	Replace T12 with Super T8 lighting	3,810	0	$432	–7	$(87)	$165	$510	$2,865	5.6
HVAC_10F	Replace Existing Boiler with Conventional Gas Boiler – 84% Combustion Efficiency	0	0	$–	106	$1,313	$268	$1,581	$9,190	5.8
Totals		*2,243,477*	*113*	*$279,754*	*982*	*$17,927*	*$34,065*	*$331,747*	*$169,176*	*0.5*

Table ES12. Summary of ECMs requiring investments between $10k and $200k and yielding a simple payback of less than 10 yrs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
HVAC #4	Re–Commissioning Of HVAC Systems And Controls	15,750,000	0	1,968,750	70,313	871,172	$–	$2,839,922	$160,000	$0.1
CEP #2	Gas Metering For Main CEP In Building 604	0	0	0	40,000	495,600	$–	$495,600	$69,384	$0.1
LI_5W	Replace incandescent lights with CFL	1,463,011	334	179,577	–2,261	–41,420	$66,393	$204,550	$75,935	$0.4
LI_5G	Replace incandescent lights with CFL	526,356	100	67,184	–995	–15,197	$22,711	$74,698	$28,602	$0.4
HVAC #6	Switch Off Boilers in Holleder Center; Use Local Gas Burners to Regenerate Desiccant Wheel in De–humidifier	64,500	0	8,063	900	11,151	$–	$19,214	$10,000	$0.5
LI_5P	Replace incandescent lights with CFL	530,459	71	62,315	–1,000	–12,388	$24,527	$74,454	$40,562	$0.5
LI_5M	Replace incandescent lights with CFL	204,564	35	23,899	–428	–5,306	$9,307	$27,900	$15,259	$0.5
LI_5T	Replace incandescent lights with CFL	525,769	91	61,778	–1,132	–14,031	$24,107	$71,854	$39,867	$0.6
LI_5Q	Replace incandescent lights with CFL	208,960	36	24,551	–447	–5,537	$9,634	$28,648	$15,932	$0.6
LI_5R	Replace incandescent lights with CFL	174,963	33	20,567	–360	–4,458	$8,175	$24,284	$13,520	$0.6
LI_5N	Replace incandescent lights with CFL	663,513	121	80,834	–1,707	–21,669	$30,713	$89,878	$50,355	$0.6
LI_5C	Replace incandescent lights with CFL	135,106	19	16,339	–268	–3,326	$5,335	$18,348	$10,358	$0.6
LI_5J	Replace incandescent lights with CFL	393,008	114	53,864	–643	–7,971	$16,713	$62,606	$36,565	$0.6
LI_5S	Replace incandescent lights with CFL	181,997	32	21,392	–424	–6,423	$8,342	$23,311	$13,677	$0.6
SHW_1D	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank	0	0	0	2,778	34,416	$133	$34,549	$20,278	$0.6
LI_5V	Replace incandescent lights with CFL	369,856	67	43,550	–897	–12,595	$17,155	$48,110	$28,371	$0.6
LI_5O	Replace incandescent lights with CFL	232,698	41	27,318	–572	–8,858	$10,743	$29,203	$17,767	$0.6
CON #4	Keller Army Hospital AHUs Retrofit And Controls	772,000	0	96,500	16,800	208,152	$–	$304,652	$200,000	$0.7
CEP #6	Interconnect The North And The Central Heating Distribution System	0	0	0	22,680	281,005	$–	$281,005	$200,000	$0.7
LI_6S	Replace existing exit signs with electroluminescent exit signs	66,527	8	7,920	0	0	$15,387	$23,307	$16,802	$0.7
LI_5H	Replace incandescent lights with CFL	112,539	50	14,787	0	0	$4,938	$19,725	$14,610	$0.7

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
SHW_1A	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank	463,932	55	55,531	−1,297	−16,074	$(249)	$39,208	$29,359	$0.7
DIN #1	Modify Kitchen Hoods with End Skirts, Bldg 745	95,200	0	11,900	1,114	13,802	$—	$25,702	$19,600	$0.8
CON #2	Reduce HVAC Run Time / Schedule AHUs To Match Building Occupancy	86,000	0	10,750	1,233	15,277	$—	$26,027	$20,000	$0.8
SHW_1C	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank	0	0	0	1,838	22,771	$(14)	$22,757	$18,042	$0.8
BE_6Q	Suspended Ceiling: Increase Insulation by R−19	220,096	269	36,446	9,020	111,764	$—	$148,210	$137,712	$0.9
SHW_1I	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank, LFSHs, Aerators	251,455	30	29,989	−731	−9,052	$(143)	$20,794	$20,163	$1.0
LI_6A	Replace existing exit signs with electroluminescent exit signs	212,477	24	25,320	0	0	$14,772	$40,092	$40,166	$1.0
SHW_1L	Replace existing water heaters with Conventional Distillate Oil Boiler – 86.5% Combustion Efficiency, Wrap Tank, Aerators	0	0	0	1,164	24,970	$335	$25,305	$25,936	$1.0
LI_6J	Replace existing exit signs with electroluminescent exit signs	115,470	13	13,736	−44	−539	$8,014	$21,211	$21,790	$1.0
LI #1	Use Occupancy Sensors to Shut off Lights, Buildings 663, 714 727 & Various Barracks	363,886	0	45,486	0	0	$—	$45,486	$48,900	$1.1
LI_6G	Replace existing exit signs with electroluminescent exit signs	123,969	19	15,112	−255	−3,156	$7,820	$19,776	$21,264	$1.1
LI_6I	Replace existing exit signs with electroluminescent exit signs	176,136	27	21,428	−426	−5,980	$11,007	$26,455	$29,928	$1.1
LI_6E	Replace existing exit signs with electroluminescent exit signs	361,357	56	43,999	−939	−11,917	$22,882	$54,964	$62,218	$1.1
LI_6H	Replace existing exit signs with electroluminescent exit signs	110,781	17	13,503	−264	−3,989	$6,952	$16,466	$18,902	$1.1
LI_6F	Replace existing exit signs with electroluminescent exit signs	65,062	9	7,875	−161	−2,484	$4,055	$9,446	$11,026	$1.2
LI_6Q	Replace existing exit signs with electroluminescent exit signs	58,321	7	6,950	−135	−1,672	$4,055	$9,333	$11,026	$1.2
LI_6P	Replace existing exit signs with electroluminescent exit signs	66,820	8	7,944	−166	−2,057	$4,634	$10,521	$12,601	$1.2
HVAC #9	Install CO_2 Controls In The Keller Army Hospital	56,000	0	7,000	6,100	75,579	$—	$82,579	$100,000	$1.2
CON #9	Fix Failed Controls in PX, Building 1204	190,000	0	23,750	3,310	41,011	$—	$64,761	$85,000	$1.3
BE_6G	Attic Ceiling: Increase Insulation by R−30 (blow−in cellulose)	0	0	0	1,715	31,407	$—	$31,407	$51,508	$1.6
BE_6H	Attic Ceiling: Increase Insulation by R−30 (blow−in cellulose)	0	0	0	3,359	51,287	$—	$51,287	$85,322	$1.7
BE_6U	Suspended Ceiling: Increase Insulation by R−38	14,947	48	4,545	1,511	18,724	$—	$23,269	$39,202	$1.7

ECM #	ECM Description	Electrical Savings KWh/yr	kW Demand	$/yr	Thermal MMBtu/yr	$/yr	Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
SHW_1G	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank, LFSHs	0	0	0	530	6,569	$(101)	$6,468	$10,965	$1.7
SHW_1F	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank, LFSHs	164,413	0	17,424	–439	–5,434	$(116)	$11,874	$20,220	$1.7
BE_6L	Attic Ceiling: Increase Insulation by R–38 (blow–in cellulose)	55,390	58	9,088	2,334	35,326	$–	$44,414	$77,715	$1.7
BE_6D	Attic Ceiling: Increase Insulation by R–30 (blow–in cellulose)	26,963	39	5,314	1,965	24,349	$–	$29,663	$54,199	$1.8
BE_6M	Attic Ceiling: Increase Insulation by R–38 (blow–in cellulose)	131,003	138	21,628	5,578	78,361	$–	$99,989	$182,706	$1.8
BE_6E	Attic Ceiling: Increase Insulation by R–30 (blow–in cellulose)	36,341	66	7,389	2,707	33,544	$–	$40,933	$75,455	$1.8
LI_6U	Replace existing exit signs with electroluminescent exit signs	80,595	12	9,785	–93	–1,234	$11,550	$20,101	$37,804	$1.9
HVAC #2	Heat Recovery from Computer Room Air–conditioning	0	0	0	2,047	25,362	$–	$25,362	$50,000	$2.0
LI_6T	Replace existing exit signs with electroluminescent exit signs	31,945	5	3,862	–55	–782	$4,813	$7,893	$15,751	$2.0
BE_6W	Suspended Ceiling: Increase Insulation by R–38	–15,826	251	12,809	4,708	62,606	$–	$75,415	$155,278	$2.1
BE_6F	Attic Ceiling: Increase Insulation by R–30 (blow–in cellulose)	0	0	0	1,503	24,996	$–	$24,996	$52,436	$2.1
DIN #3	Heat Recovery from Refrigeration Machines, Building 745	0	0	0	3,100	38,409	$–	$38,409	$85,000	$2.2
HVAC_11E	Replace Existing Boiler with Natural Gas Infrared Heating System – High Efficiency	–1,758	0	–189	314	7,275	$413	$7,499	$16,606	$2.2
HVAC_11F	Replace Existing Boiler with Natural Gas Infrared Heating System – Medium Efficiency	0	0	0	1,015	21,521	$4,290	$25,811	$57,832	$2.2
HVAC_10J	Replace Existing Boiler with Conventional Gas Boiler – 84% Combustion Efficiency	0	0	0	86	5,568	$251	$5,819	$13,326	$2.3
SHW_1K	Replace existing water heaters with Conventional Gas Boiler – 84% Combustion Efficiency, Wrap Tank	153,569	22	18,798	–498	–6,166	$63	$12,695	$29,961	$2.4
HVAC_10G	Replace Existing Boiler with Conventional Gas Boiler – 84% Combustion Efficiency	0	0	0	209	13,527	$402	$13,929	$33,628	$2.4
LI_9B	Replace T12 with Super T8 lighting	511,116	72	61,718	–1,180	–14,620	$13,355	$60,453	$149,602	$2.5
HVAC_10C	Replace Existing Boiler with Condensing Gas Boiler – 91% Combustion Efficiency	293	0	27	578	29,003	$(998)	$28,032	$70,449	$2.5
SHW_1J	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank, LFSHs, Aerators	0	0	0	587	7,272	$(112)	$7,160	$19,505	$2.7
BE_6P	Suspended Ceiling: Increase Insulation by R–19	0	0	0	1,653	20,480	$–	$20,480	$60,029	$2.9
BE_6T	Suspended Ceiling: Increase Insulation by R–38	6,741	27	1,502	1,388	17,194	$–	$18,696	$56,294	$3.0

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
BE_5O	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	0	0	0	1,307	19,946	$–	$19,946	$60,310	$3.0
HVAC_10H	Replace Existing Boiler with Conventional Gas Boiler – 84% Combustion Efficiency	0	0	0	95	9,686	$590	$10,276	$32,190	$3.1
HVAC_11A	Replace Existing Boiler with LPG Infrared Heating System – High Efficiency	0	0	0	2,209	40,467	$3,181	$43,648	$142,828	$3.3
BE_6V	Suspended Ceiling: Increase Insulation by R–38	35,755	90	7,916	3,221	39,910	$–	$47,826	$158,134	$3.3
LI_10A	Replace metal halide high–bay lighting with T5 lighting	15,826	4	2,133	0	0	$4,136	$6,269	$21,429	$3.4
BE_6O	Suspended Ceiling: Increase Insulation by R–19	2,345	0	259	480	5,951	$–	$6,210	$21,544	$3.5
BE_5L	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–1,758	49	1,218	3,722	46,121	$–	$47,339	$168,659	$3.6
BE_5K	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–2,051	8	41	559	6,921	$–	$6,962	$25,880	$3.7
DIN #2	Repair Freezer Door Sears, Building 745	41,800	0	5,225	0	0	$–	$5,225	$20,000	$3.8
LI_7B	Replace T8 lighting with Super T8 lighting	134,227	38	18,277	–146	–1,804	$3,428	$19,901	$78,108	$3.9
WATER #1	Fix Cooling Tower Leaks	–10,000	0	–1,250	0	0	$–	$34,540	$140,000	$4.1
BE_6N	Suspended Ceiling: Increase Insulation by R–11	188,445	292	18,798	0	0	$–	$18,798	$77,053	$4.1
BE_5F	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–11,137	18	–740	807	10,742	$–	$10,002	$41,725	$4.2
HVAC_11B	Replace Existing Furnace with LPG Infrared Heating System – High Efficiency	0	0	0	1,163	21,310	$1,141	$22,451	$104,383	$4.6
HVAC_11D	Replace Existing Steam FCU with Natural Gas Infrared Heating System – High Efficiency	–3,224	0	–346	295	6,957	$(311)	$6,300	$31,059	$4.9
HVAC_11C	Replace Existing Steam AHU with Natural Gas Infrared Heating System – High Efficiency	–1,465	0	–152	125	2,961	$(132)	$2,677	$13,223	$4.9
LI_10B	Replace metal halide high–bay lighting with T5 lighting	19,050	3	2,371	–24	–297	$1,154	$3,228	$16,434	$5.1
BE_6J	Attic Ceiling: Increase Insulation by R–30 (blow–in cellulose)	24,325	20	3,737	672	8,323	$–	$12,060	$64,029	$5.3
BE_6K	Attic Ceiling: Increase Insulation by R–30 (blow–in cellulose)	34,582	50	6,233	2,348	29,086	$–	$35,319	$188,815	$5.3
LI_7A	Replace T8 lighting with Super T8 lighting	50,115	14	6,877	–37	–461	$842	$7,258	$39,565	$5.5
LI_9E	Replace T12 with Super T8 lighting	27,842	4	3,259	–49	–602	$1,395	$4,052	$22,096	$5.5
LI_9I	Replace T12 with Super T8 lighting	27,549	5	3,244	–55	–681	$1,371	$3,934	$21,717	$5.5
HVAC_10K	Replace Existing Boiler with Conventional LPG Boiler – 84% Combustion Efficiency	0	0	0	605	11,079	$884	$11,963	$66,056	$5.5
BE_6I	Attic Ceiling: Increase Insulation by R–30 (blow–in cellulose)	4,396	9	962	406	5,032	$–	$5,994	$33,465	$5.6

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
LI_9A	Replace T12 with Super T8 lighting	143,312	41	19,532	–297	–3,682	$4,616	$20,466	$114,564	$5.6
HVAC_10B	Replace Existing Boiler with Condensing Gas Boiler – 91% Combustion Efficiency	0	0	0	708	8,766	$(257)	$8,509	$49,286	$5.8
LI_9K	Replace T12 with Super T8 lighting	19,343	3	2,283	–43	–614	$976	$2,645	$15,455	$5.8
LI_9C	Replace T12 with Super T8 lighting	34,875	6	4,157	–83	–1,055	$1,583	$4,685	$27,430	$5.9
LI_6AK	Replace existing exit signs with electroluminescent exit signs	5,861	1	717	–5	–58	$2,834	$3,493	$22,052	$6.3
BE_5G	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	0	0	0	143	1,771	$–	$1,771	$11,193	$6.3
LI_6AD	Replace existing exit signs with electroluminescent exit signs	3,224	0	397	–6	–77	$1,619	$1,939	$12,601	$6.5
LI_6AF	Replace existing exit signs with electroluminescent exit signs	2,638	0	310	–2	–24	$1,518	$1,804	$11,814	$6.5
LI_6AA	Replace existing exit signs with electroluminescent exit signs	3,224	1	401	–5	–64	$1,822	$2,159	$14,176	$6.6
BE_6S	Suspended Ceiling: Increase Insulation by R–19	2,051	2	685	480	8,789	$–	$9,474	$64,222	$6.8
BE_5E	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–2,345	5	–163	281	3,478	$–	$3,315	$22,536	$6.8
BE_5J	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	0	0	0	155	1,926	$–	$1,926	$13,099	$6.8
HVAC_12A	Replace Existing Furnace with Condensing Gas Furnace – 92% Efficient	2,638	0	312	2,151	26,654	$(949)	$26,017	$177,576	$6.8
HVAC_10A	Replace Existing Boiler with Condensing Gas Boiler – 91% Combustion Efficiency	0	0	0	718	8,901	$(132)	$8,769	$60,457	$6.9
LI_7F	Replace T8 lighting with Super T8 lighting	58,321	6	6,946	0	0	$15	$6,961	$49,017	$7.0
HVAC_14A	Replace existing with Single Zone Packaged AC Unit (very high efficiency / medium)	92,317	26	11,754	0	0	$54	$11,808	$87,243	$7.4
BE_5H	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–2,638	4	–187	212	2,622	$–	$2,435	$18,204	$7.5
HVAC_10E	Replace Existing Boiler with Conventional Gas Boiler – 84% Combustion Efficiency	0	0	0	176	2,178	$27	$2,205	$16,485	$7.5
BE_9E	Install Thermal Break Aluminum Frame Double Pane Argon/Low–e Window	0	0	0	940	17,223	$–	$17,223	$134,378	$7.8
LI_8A	Replace MH with Biaxial Florescent lighting	109,609	31	14,963	–100	–1,236	$4,701	$18,428	$145,713	$7.9
BE_7B	Add Insulation to Interior Surface of Metal Roof: 4–in. Fiberglass	19,050	48	4,729	1,275	18,075	$–	$22,804	$189,117	$8.3
LI_8B	Replace MH with Biaxial Florescent lighting	50,701	12	6,344	–32	–391	$2,541	$8,494	$70,963	$8.4
LI_8C	Replace MH with Biaxial Florescent lighting	27,842	6	3,472	–17	–215	$1,391	$4,648	$38,846	$8.4
BE_9B	Install Thermal Break Aluminum Frame Double Pane Argon/Low–e Window	–7,913	5	–717	1,074	13,302	$–	$12,585	$107,073	$8.5

ECM #	ECM Description	Electrical Savings KWh/yr	Electrical Savings kW Demand	Electrical Savings $/yr	Thermal MMBtu/yr	Thermal $/yr	Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
BE_6R	Suspended Ceiling: Increase Insulation by R–19	1,172	4	294	265	3,287	$–	$3,581	$30,623	$8.6
LI_7G	Replace T8 lighting with Super T8 lighting	60,959	9	7,588	–56	–694	$1,259	$8,153	$69,964	$8.6
BE_5M	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	7,620	5	951	390	4,830	$–	$5,781	$49,882	$8.6
BE_6B	Attic Ceiling: Increase Insulation by R–13 (blow–in cellulose)	18,170	13	2,519	519	6,426	$–	$8,945	$78,086	$8.7
HVAC_12C	Replace Existing Furnace with Condensing LPG Furnace – 92% Efficient	–11,430	0	–1,314	340	6,086	$(255)	$4,517	$40,349	$8.9
BE_5A	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	16,705	6	1,439	0	0	$–	$1,439	$12,967	$9.0
BE_9D	Install Thermal Break Aluminum Frame Double Pane Argon/Low–e Window	0	0	0	529	8,791	$–	$8,791	$80,471	$9.2
HVAC_12B	Replace Existing Furnace with Condensing Gas Furnace – 92% Efficient	–33,410	0	–3,776	1,086	13,458	$(484)	$9,198	$87,865	$9.6
BE_6C	Attic Ceiling: Increase Insulation by R–19 (blow–in cellulose)	879	4	266	112	1,383	$–	$1,649	$15,760	$9.6
LI_7K	Replace T8 lighting with Super T8 lighting	83,818	23	11,368	–93	–1,148	$1,053	$11,273	$109,659	$9.7
BE_8E	Blow–in Wall Insulation to Fill Available Space	0	0	0	541	9,908	$–	$9,908	$98,217	$9.9
Totals		*25,934,382*	*2,052*	*$3,234,941*	*182,857*	*$2,288,051*	*$374,579*	*$5,897,571*	*$2,512,324*	*0.4*

Table ES13. Summary of ECMs requiring an investment > $200k and yielding a simple payback < 6 yrs.

ECM #	ECM Description	Electrical Savings KWh/yr	Electrical Savings kW Demand	Electrical Savings $/yr	Thermal MMBtu/yr	Thermal $/yr	Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
BE_7A	Add insulation to interior surface of metal roof: 4-in. fiberglass	6,620	1,986	$313,768	$67,392	$855,393	$–	$1,169,161	$585,439	0.5
CEP #9_A	Abandon CEP 604 and install heating and hot water systems in buildings	–1,078	–305	$(30,006)	$289,127	$3,289,386	$275,879	$3,535,259	$3,207,715	0.9
HVAC #8	Do not replace AHUs at the Keller Army Hospital	0	0	$–	$–	$–	$–	$500,000	$500,000	1.0
CEP #5	Longer use of the backpressure steam turbine by increasing the low pressure steam demand	4,094	0	$150,000	$–	$–	$–	$150,000	$240,000	1.6

ECM #	ECM Description	Electrical Savings KWh/yr	Electrical Savings kW Demand	Electrical Savings $/yr	Thermal MMBtu/yr	Thermal $/yr	Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
HVAC #3C	New solutions for re–heat bypass cooling coil, Bldg 655	3,873	0	$141,875	$2,867	$35,522	$–	$177,397	$317,000	1.8
HVAC #3A	New solutions for re–heat condenser heat, Bldg 655	3,873	0	$141,875	$2,867	$35,522	$–	$177,397	$323,000	1.8
CEP #7	Hot water conversion and replacement of the unstable tunnels	0	0	$–	$7,200	$89,208	$240,000	$329,208	$700,000	2.1
HVAC #3B	New solutions for re–heat heat exchanger, Bldg 655	3,849	0	$141,025	$2,867	$35,522	$–	$176,547	$483,000	2.7
CEP #3	Small boiler In CEP building 845 (laundry boiler)	0	0	$–	$22,680	$281,005	$–	$281,005	$800,850	2.8
LI_9L	Replace T12 with Super T8 lighting	1,443	123	$58,276	$(368)	$(4,891)	$21,417	$74,802	$372,718	5.0
Totals		*22,673*	*1,804*	*916,813*	*394,632*	*4,616,667*	*537,296*	*6,570,777*	*7,529,722*	*1.1*

Table ES14. Summary of ECMs with greatest maintenance savings.

ECM #	ECM Description	Electrical Savings KWh/yr	Electrical Savings kW Demand	Electrical Savings $/yr	Thermal MMBtu/yr	Thermal $/yr	Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
LI_5I	Replace incandescent lights with CFL	490	32	$18,919	$(86)	$(1,069)	$5,122	$22,972	$7,267	0.3
LI_5C	Replace incandescent lights with CFL	461	19	$16,339	$(268)	$(3,326)	$5,335	$18,348	$10,358	0.6
LI_6H	Replace existing exit signs with electroluminescent exit signs	378	17	$13,503	$(264)	$(3,989)	$6,952	$16,466	$18,902	1.1
LI_7J	Replace T8 lighting with Super T8 lighting	510	26	$18,430	$–	$–	$7,682	$26,112	$254,576	9.7
LI_6G	Replace existing exit signs with electroluminescent exit signs	423	19	$15,112	$(255)	$(3,156)	$7,820	$19,776	$21,264	1.1
LI_6J	Replace existing exit signs with electroluminescent exit signs	394	13	$13,736	$(44)	$(539)	$8,014	$21,211	$21,790	1.0
LI_5R	Replace incandescent lights with CFL	597	33	$20,567	$(360)	$(4,458)	$8,175	$24,284	$13,520	0.6
LI_5S	Replace incandescent lights with CFL	621	32	$21,392	$(424)	$(6,423)	$8,342	$23,311	$13,677	0.6
LI_9N	Replace T12 with Super T8 lighting	54	2	$1,956	$(26)	$(479)	$8,919	$10,396	$118,006	11.4
LI_9M	Replace T12 with Super T8 lighting	55	2	$1,991	$(23)	$(377)	$9,079	$10,693	$120,131	11.2
LI_5M	Replace incandescent lights with CFL	698	35	$23,899	$(428)	$(5,306)	$9,307	$27,900	$15,259	0.5
LI_5Q	Replace incandescent lights with CFL	713	36	$24,551	$(447)	$(5,537)	$9,634	$28,648	$15,932	0.6

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
LI_5O	Replace incandescent lights with CFL	794	41	$27,318	$(572)	$(8,858)	$10,743	$29,203	$17,767	0.6
LI_6I	Replace existing exit signs with electroluminescent exit signs	601	27	$21,428	$(426)	$(5,980)	$11,007	$26,455	$29,928	1.1
LI_6U	Replace existing exit signs with electroluminescent exit signs	275	12	$9,785	$(93)	$(1,234)	$11,550	$20,101	$37,804	1.9
LI_9B	Replace T12 with Super T8 lighting	1,744	72	$61,718	$(1,180)	$(14,620)	$13,355	$60,453	$149,602	2.5
LI_6A	Replace existing exit signs with electroluminescent exit signs	725	24	$25,320	$–	$–	$14,772	$40,092	$40,166	1.0
LI_6S	Replace existing exit signs with electroluminescent exit signs	227	8	$7,920	$–	$–	$15,387	$23,307	$16,802	0.7
LI_5J	Replace incandescent lights with CFL	1,341	114	$53,864	$(643)	$(7,971)	$16,713	$62,606	$36,565	0.6
LI_5V	Replace incandescent lights with CFL	1,262	67	$43,550	$(897)	$(12,595)	$17,155	$48,110	$28,371	0.6
LI_9L	Replace T12 with Super T8 lighting	1,443	123	$58,276	$(368)	$(4,891)	$21,417	$74,802	$372,718	5.0
LI_5G	Replace incandescent lights with CFL	1,796	100	$67,184	$(995)	$(15,197)	$22,711	$74,698	$28,602	0.4
LI_6E	Replace existing exit signs with electroluminescent exit signs	1,233	56	$43,999	$(939)	$(11,917)	$22,882	$54,964	$62,218	1.1
LI_5T	Replace incandescent lights with CFL	1,794	91	$61,778	$(1,132)	$(14,031)	$24,107	$71,854	$39,867	0.6
LI_5P	Replace incandescent lights with CFL	1,810	71	$62,315	$(1,000)	$(12,388)	$24,527	$74,454	$40,562	0.5
LI_5N	Replace incandescent lights with CFL	2,264	121	$80,834	$(1,707)	$(21,669)	$30,713	$89,878	$50,355	0.6
LI_5W	Replace incandescent lights with CFL	4,992	334	$179,577	$(2,261)	$(41,420)	$66,393	$204,550	$75,935	0.4
CEP #7	Hot water conversion and replacement of the unstable tunnels	0	0	$–	$7,200	$89,208	$240,000	$329,208	$700,000	2.1
CEP #9_A	Abandon CEP 604 and install heating and hot water systems in buildings	–1,078	–305	$(30,006)	$289,127	$3,289,386	$275,879	$3,535,259	$3,207,715	0.9
Totals		*26,616*	*1,222*	*965,255*	*$281,489*	*$3,171,164*	*$933,692*	*$5,070,111*	*$5,565,659*	*1.1*

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Preface

The Installation Management Command (IMCOM) funded an Annex 46 energy assessment initiative to visit various Army installations to identify and initiate energy-related projects that could enable the installations to better meet the energy reduction requirements mandated by Executive Order 13123, Energy Policy Act (EPAct) 1992 and EPACT 2005. One of the initiative's most important goals is to assist the installations in not only determining the projects, but also in determining applicable funding and execution methods. This study was conducted for West Point under the Annex 46 program. The technical monitors were Paul LeBlond, Energy Manager, West Point, Frank Bloomer, Deputy Engineer, West Point, and Paul Volkman, Headquarters, Installation Management Command (HQIMCOM).

The work was performed by the Energy Branch (CF-E), of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The Energy Team, as funded by IMCOM, was composed of individuals from the Army Corps of Engineers Engineering and Research Center, Construction Engineering Research Laboratory (CERL), Facilities Division (CF), Energy Branch (CF-E) and the Pacific Northwest National Laboratory. Each organization provided individuals to the team that have expertise in various engineering and energy-related fields. Appreciation is owed to Mathew Talaber, Director of Public Works West Point and his staff for their coordination of the Energy Team and to the West Point Directorate of Public Works (DPW) who contributed significantly to the information gathering and feasibility analysis. The CERL principal investigator was David Underwood. The associated Technical Director was Martin J. Savoie, CEERD-CV-T. The Director of ERDC-CERL is Dr. Ilker R. Adiguzel.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Richard B. Jenkins, and the Director of ERDC is Dr. James R. Houston.

Unit Conversion Factors

Multiply	By	To Obtain
Acres	4,046.873	square meters
British thermal units (BTU, International Table)	1,055.056	joules
MMBtu	0.293	MWh
MBtu	1,000	Btu
MMBtu	1,000,000	Btu
cubic feet	0.02831685	cubic meters
cubic inches	1.6387064 E-05	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
Feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
Inches	0.0254	meters
miles (U.S. statute)	1,609.347	meters
miles per hour	0.44704	meters per second
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square miles	2.589998 E+06	square meters
tons (2,000 pounds, mass)	907.1847	kilograms
tons (2,000 pounds, mass) per square foot	9,764.856	kilograms per square meter

1 Introduction

1.1 Background

West Point is the home of the U.S. Military Academy, the purpose of which is to:

> provide the Nation with leaders of character who serve the common defense." To achieve its purpose, the mission of the West Point is "to educate, train, and inspire the Corps of Cadets so that each graduate is a commissioned leader of character committed to the values of Duty, Honor, Country; professional growth throughout a career as an officer in the U.S. Army; and a lifetime of selfless service to the nation.

West Point is located on the west bank of the Hudson River, approximately 50 mi north of New York City and 15 mi south of Newburgh. In addition to being a college campus with academic, social, and athletic activities, West Point is a military installation, a National Historical Landmark, and a national tourist attraction. West Point was officially recognized for its historical significance and contributions to the country in 1960 when this rocky highland was declared a National Historic Landmark. It is estimated that almost 3 million tourists from around the world visit here annually to walk the grounds, observe cadets and enjoy a day at West Point.

As the oldest continually occupied post in our country's history, West Point is home for more than 1,400 military personnel. Although most military personnel are members of the Academy's staff and faculty and assigned to the 1st Battalion of the 1st Infantry, the installation also includes several tenant units and activities. West Point is currently undergoing an extensive Revitalization Program that will greatly improve the quality of cadet life. As part of this program, the Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) undertook this study to identify energy inefficiencies and wastes at West Point and propose energy-related projects to enable the installation to better meet the energy reduction requirements mandated by Executive Order 13123 and EPACT 2005.

1.2 Objectives

The objectives of this study were to identify energy inefficiencies and wastes at West Point and to propose energy-related projects with applicable funding and execution methods that could enable the installations to better meet the energy reduction requirements mandated by Executive Order 13123 and EPACT 2005.

1.3 Annex 46 project team and summary of activities

Subject matter experts (SMEs) from the following organizations cooperated to accomplish this project:

- *ERDC-CERL* implemented an Energy Assessment methodology, which was previously developed as part of the "Industrial Process Modeling and Optimization" program under the auspices of the IEA ECBCS Programme Annex 46 "Holistic Assessment Toolkit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo)." The protocol is designed to assist energy managers and Regional Energy Managers to develop energy conservation projects (self-help for energy managers).
- *Pacific Northwest National Laboratory (PNNL)* developed an installation-wide energy model of West Point using the Facility Energy Decision System (FEDS) software. PNNL used FEDS to develop a list of 220 life cycle cost-effective energy- and cost-reducing retrofit measures.
- *Private contractors* with various technical expertise were a vital part of the Energy Team. Since West Point has an aging central heating plants, an expert on central plants and, in particular, system conversions from steam to hot water was brought into the team. Other experts in heating, ventilating, and air-conditioning (HVAC), building envelope, and lighting rounded out the contractor portion of the team.

1.4 Approach

1.4.1 General

This study was conducted using an Energy Assessment Protocol developed by CERL in combination with a FEDS analysis conducted by PNNL. This process is unique in that it combines a "ground level" survey of existing systems with a "higher level" model-based assessment of the installation

based on data gathered from a small number of buildings deemed to be representative of groups of buildings having similar occupancy, construction type, vintage, etc. While either an Energy Assessment Protocol or a FEDS analysis could be conducted and provide standalone output, the combining of these processes should produce a superior end result in that the output of the ground level Energy Assessment Protocol is used as input to help calibrate and refine the FEDS model of the installation's energy systems. The resulting enhanced FEDS model is then executed to extrapolate the energy and financial impacts of implementing packages of energy conservation measures (ECMs) on an installation-wide basis. At West Point, FEDS was used to examine the impact from using the specific ECMs proposed by the Annex 46 team in addition to a list of 220 other energy cost-reducing retrofit measures identified by FEDS. The impact of implementing these ECMs was extrapolated to all appropriate buildings at West Point to predict the total installation energy reduction impact. The general process was:

1. Make an initial site visit to, among other items, determine the Site's major energy issues and familiarize the Energy Team with installation and operations
2. Assemble a team of SMEs with expertise in technical areas relating to those identified in the initial site visit
3. Make a Technical Assessment visit with the SMEs and FEDS team to:
   a. Make building-specific Energy Conservation Measure (ECM) evaluations
   b. Gather data for installation-wide FEDS model development and calibration
   c. Calibrate FEDS model for entire installation
   d. FEDS optimization of ECMs for cost effectiveness
   e. Analyze findings and develop implementation strategies.

1.4.2 FEDS analysis

The number of conceivable energy conservation measures, fuel-switching opportunities, and renewable-energy projects at Federal sites is potentially enormous. The FEDS model is used to cost-effectively identify energy saving opportunities for a given site. FEDS is a Windows-based software tool that was developed by PNNL to provide a comprehensive method to quickly and objectively identify energy improvements that offer maximum life-cycle cost savings by determining an optimum set of cost-effective ret-

rofits from a current database of hundreds of proven technologies. These retrofit candidates include heating, cooling, lighting, motors, building envelopes, and hot water systems. Interactive effects are also evaluated as part of the optimization process so that energy savings are not double counted or undercounted. The results are based on life-cycle cost economics consistent with 10 CFR 436.

The general approach taken by FEDS is to develop a model of the buildings and energy-related infrastructure at an installation, calibrate that model to actual historic energy use, and then use the model to predict energy consumption and identify cost-effective retrofits under typical meteorological year (TMY) weather conditions. The model was calibrated using 2006 steam consumption from West Point facility logs, and the results are based on the current operation of the steam plant. The model used Typical Meteorological Year weather data, so the results are not specific to 2007.

Building inventory data for a given installation are obtained from existing corporate databases, if available. From this data, building groups that reasonably describe the installation's building stock are developed and each building on the installation is assigned to one of these building groups based on building type (use), size (square footage), and vintage (age). Within each building group, at least one facility is designated to be representative of the group.

Beyond the information available from corporate databases, building characteristics for each facility category are further developed from a combination of walk-through audits of the representative buildings within each building group, discussions with knowledgeable site personnel and inferencing relationships within the FEDS model (driven by building type, size, climate, and vintage).

Development of an installation energy model includes characterization of non-building energy-related infrastructure such as central energy plants, central chiller plants, electrical distribution systems, etc. To the extent available, historic information such as boiler logs, meter readings, billing data, and easily observable characteristics such as steam distribution system loop length, pipe diameter, insulation level, pipe location (in/above ground), steam temperature, and leakage rate of flow are entered as inputs to the FEDS model.

FEDS simulates building and central plant energy use combined with other loads' consumption to predict the total site energy consumption for the most recent year with complete data at the time of the analysis. Uncertain elements of the modeling assumptions are adjusted until the model's energy consumption prediction matches "reasonably well" with actual historic energy consumption. Model calibration is achieved for site "total" energy use by fuel type and also at specific buildings where submeter data were available.

Once FEDS is satisfactorily calibrated, it identifies packages of retrofits that individually and collectively minimize the life-cycle cost of building energy services, resulting in projects where the net present value of the investment is greater than or equal to zero and the savings-to-investment ratio (SIR) is greater than or equal to one. These results assume funding will be appropriated by the government; they will change slightly if financing is obtained through alternative methods (e.g., ESPC, Utility Energy Services Contract [UESC]).

1.4.3 Energy assessment protocol

This study was conducted using an Energy Assessment Protocol developed by CERL in collaboration with a team of government, institutional, and private sector parties as a part of the IEA ECBCS Program Annex 46 [https://kd.erdc.usace.army.mil/projects/ecbcs/]. This protocol is based on the analysis of information available from the literature, training materials, the documented and non-documented practical experiences of contributors, and previous successful showcase energy assessments conducted by a diverse team of experts at the U.S. Army facilities.

The Energy Assessment Protocol addresses technical and non-technical organizational capabilities required to make a successful assessment geared to identifying energy and other operating costs reduction measures without adversely impacting Indoor Air Quality, product quality, or (in the case of repair facilities) safety and morale.

A critical element for energy assessment is a capability to apply a "holistic" approach to the energy sources and sinks in the audited target (installation, building, system, and their elements). The holistic approach suggested by the protocol includes the analysis of opportunities related to the

energy generation process and distribution systems, building envelope, lighting, internal loads, HVAC, and other mechanical and energy systems. A useful way of visualizing the energy flows within a facility or process is the Sankey diagram (Figures 1 and 2).

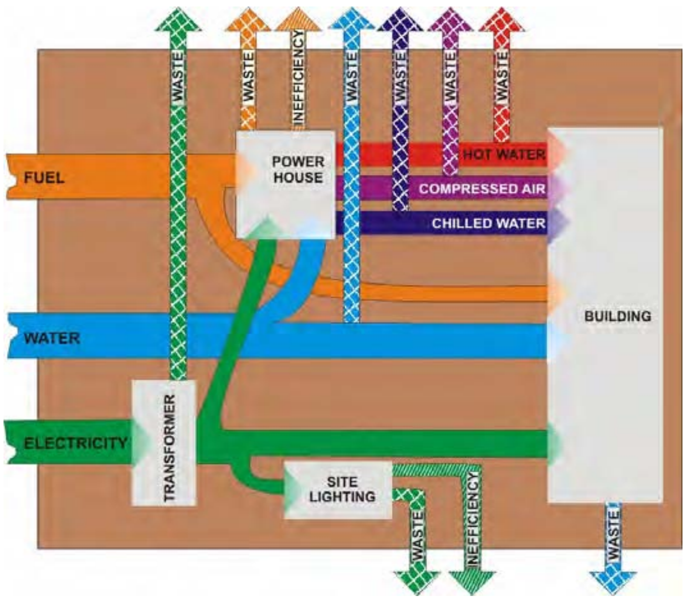

Figure 1. Example Sankey diagram of energy usage, waste, and inefficiencies for an Army installation.

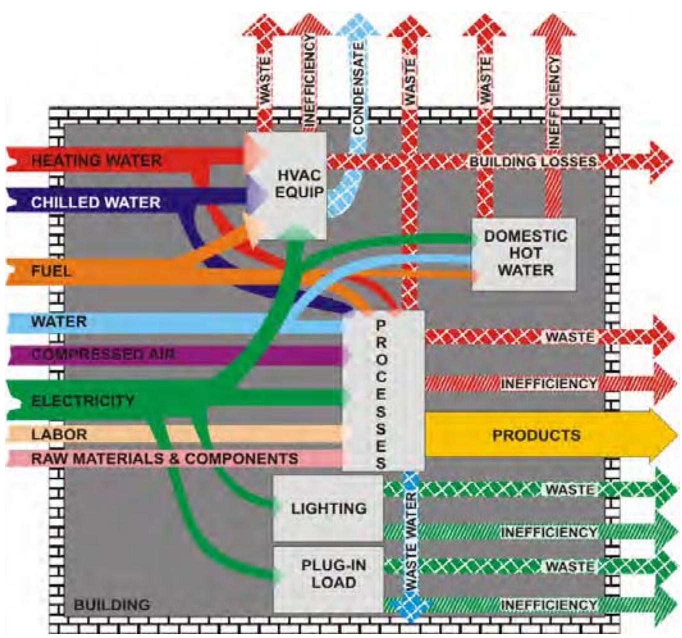

Figure 2. Example Sankey diagram of energy usage, waste, and inefficiencies for a building with production process.

The Protocol addresses several different scopes (building stock, individual building, system, and component) and levels of assessment. It distinguishes between the pre-assessment phase (Level 0: selection of objects for Energy Assessments and required composition of the audit team) and three levels of energy audits with differing degrees of rigor. Each of these three levels may be implemented in different ways: simplified or more detailed assessments, depending on the availability of energy consumption information and other data.

During the selection phase, one can choose from a building stock those facilities that have the most promising energy saving potential. Similarly, one can select from a specific building the systems to be audited or, from a system, the components to be considered for more detailed analysis. The scope and depth of the assessments differ in their objectives, methodologies, procedures, required instrumentation, and approximate duration (Figure 3).

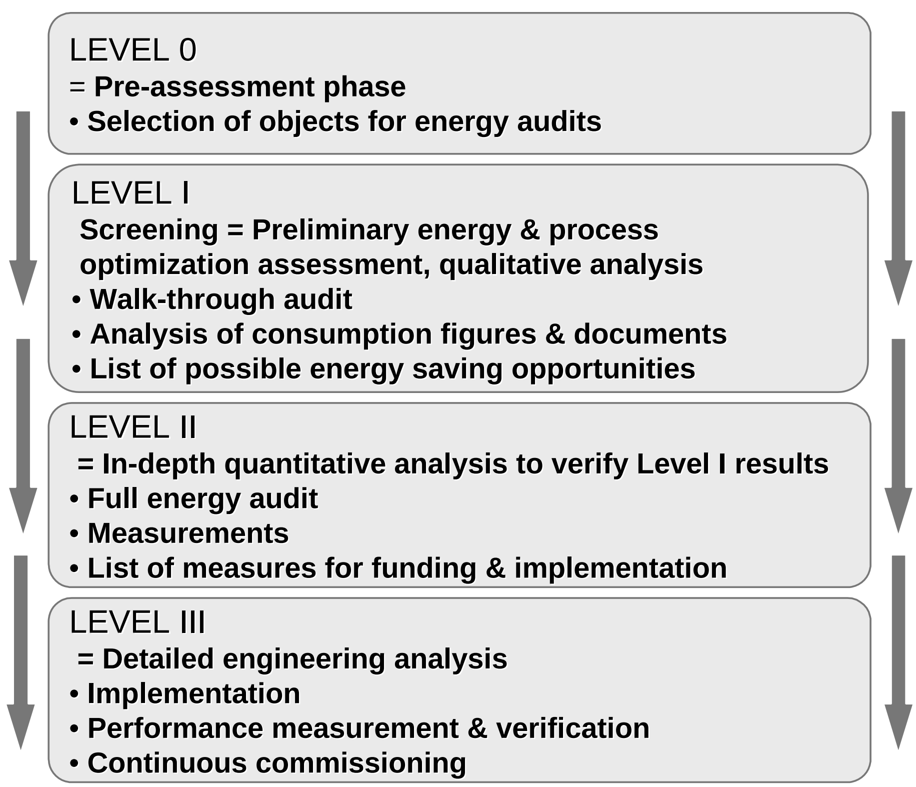

Figure 3. Scope and depth of the assessment.

1.4.4 Level I audit

A *Level I* audit (qualitative analysis) is a preliminary energy and process optimization opportunity analysis consisting primarily of a walk-through review to analyze and benchmark existing documents and consumption figures. The Level I audit takes from 2 to 5 days, and identifies the bottom-line dollar potential of energy conservation and process improvements. No engineering measurements using test instrumentation are made. If the consumption figures are not available (e.g., due to the absence of metering), which is typical for many industrial facilities and manufacturing processes, the Level I audit can be based on analyses and estimates by experienced auditors.

A Level I audit would normally recommend that the installation perform some metering, which could be followed by a Level II audit to verify the Level I assumptions, and to more fully develop the ideas from the Level I screening analysis.

1.4.5 Level II audit

A *Level II* audit (quantitative analysis) includes an analysis geared towards funds appropriation; this analysis uses calculated savings and partial instrumentation measurements with a cursory level of analysis. The Level II study typically takes 5 to 10 times the effort of a Level I, and could be accomplished over a 2- to 6-month period, depending on the scope of the effort. The Level II effort includes an in-depth analysis in which the most crucial assumptions are verified. The end product will be a group of "appropriation grade" energy and process improvement projects for funding and implementation.

1.4.6 Level III audit

Finally, the *Level III* audit (continuous commissioning) is a detailed engineering analysis with implementation, performance measurement and verification (M&V) assessment, and fully instrumented diagnostic measurements (long term measurements). This level takes 3 to 18 months to accomplish. For ESPC projects, the *Level III* audit is prolonged until the end of the contract to guarantee that all installed systems and their components operate correctly over their useful lifetimes.

1.4.7 Keys to a successful audit

The key elements that guarantee success of the Energy Assessment are:

- Involvement of key facility personnel and their on-site contractors who know what the major problems are, where they are, and have already thought of many potential solutions
- The facility personnel's sense of "ownership" of the ideas, which encourages a commitment to successful implementation
- A focus on site-specific, critical cost issues. If solved, the greatest possible economic contribution to a facility's bottom line will be realized. Major potential cost issues can include: facility use (bottlenecks), mission, labor (productivity, planning and scheduling), energy (steam, electricity, compressed air), waste (air, water, solid, hazardous), equipment (outdated or state-of-the-art).

From a strictly cost perspective, process capacity and labor use/productivity and soldiers' well-being can be far more significant than energy and environmental concerns. All of these issues, however, must be considered together to accomplish the facility's mission in the most efficient and cost-effective way.

1.4.8 General overall process

1. The process used at West Point was unique in that it combines a "ground level" survey of existing systems with a "higher level" model-based assessment of the installation based on data gathered from a small number of buildings deemed to be representative of groups of buildings having similar occupancy, construction type, vintage, etc. While either an Energy Assessment Protocol or a FEDS analysis could be conducted and provide standalone output, the combining of these processes should produce a superior end result in that the output of the ground level Energy Assessment Protocol is used as input to help calibrate and refine the FEDS model of the installation's energy systems. The resulting enhanced FEDS model is then executed to extrapolate the energy and financial impacts of implementing packages of ECMs on an installation-wide basis. At West Point, FEDS was used to examine the impact from using the specific ECMs proposed by the Annex 46 team in addition to a list of 220 other energy cost-reducing retrofit measures identified by FEDS. The impact of implement-

ing these ECMs was extrapolated to all appropriate buildings at West Point to predict the total installation energy reduction impact.

1.5 Scope

This Annex 46 Energy Optimization Assessment included a Level I study of the central energy plants and associated steam distribution systems providing heat to representative administrative buildings, laundry, dining facilities, and other buildings and an analysis of their building envelopes, ventilation air systems, and lighting.

1.6 Mode of technology transfer

The results of this work will be presented to IMCOM, Assistant Chief of Staff for Installation Management (ACSIM), and West Point for their consideration for implementation and funding and as the basis for other currently conducted studies related to energy use planning such as new central energy plants and use of renewable energy sources. It is anticipated that the results of this work will contribute to an enhanced awareness within IMCOM, the U.S. Army Corps of Engineers and its districts, and other Army organizations of opportunities to improve the overall energy efficiency of Army installations. This information will be disseminated through workshops, presentations, and professional industrial energy technology conferences. This report will also be made accessible through the World Wide Web (WWW) at: http://www.cecer.Army.mil

2 Installation Energy Use Rates and Historic Use

2.1 Utility rates and consumption

As reported by West Point, 1,123,458 MMBtu were consumed in fiscal year 2007 (FY07) and 1,214,839 MMBtu in FY06. Natural gas consumption was 798,996 kcf; fuel oil consumption was 231,312 gallons; propane consumption was 1,375 kcf; electricity consumption was 84,714 MWh. Table 1 lists West Point energy costs for FY07. The electricity cost is the blended rate.

Table 1. West Point energy costs for FY07

Energy Type	Consumption	Units	Unit Price
Electricity (blended rate)	$9,931,209	MWh	$125
Natural Gas	$7,765,252	Therms	$1.239
Fuel Oil (Cairnes Field)	$453,481	Gallons	$1.95
Propane	$62,958	kcf	$7.32
Water	Unknown	kGal	$1.694

2.2 West Point electrical charges

West Point electrical charges consist a Special Contract declining block rates of an energy charge (kWh) and a demand charge (kW) shown in Table 2.

Table 2 lists the winter (01Oct–31May) and summer (01Jun–30Sep) marginal rate structure.

Table 2. Winter (01 Oct – 31 May) and summer (01 Jun – 30 Sep) marginal rate structure.

Season	Energy Rate First 300 hrs	Energy Rate over 300 hrs	Demand Rate
Winter	$0.0564/kWh	$0.05310/kWh	$8.44/kW
Summer	$0.0564/kWh	$0.05310/kWh	$11.96/kW

During FY06, West Point's peak electric demand was 8.93 MW as recorded in September 2005.

3 Building Envelope ECMs

3.1 BE #1: Establish a cool roofs strategy

3.1.1 Existing conditions and problems

Currently many roofs at West Point are dark in color. Dark colors absorb more of the sun's energy than do lighter colors, making the roof hotter than the outdoor air temperature. This is also the case with white or close-to-white roofs that do not have cool roof surfaces. The surfaces of some roofs at West Point have been painted with a silver-colored paint apparently to achieve "Cool Roof" properties. This paint still gets very hot in direct sunshinesuch that it was found to melt and stick to the shoes of energy assessment specialists inspecting the roof. (Silver paint alone does not make it a "Cool Roof.")

3.1.2 Cool roof concept

People who live in tropical climates usually wear light-colored or white clothing to help keep them cool. They know that light colors reflect heat and sunlight; whereas dark colors absorb heat and light. In general, a building with a dark-colored roof will be hotter than one with a light-colored roof.

Cool Roofs are roofs consisting of materials that very effectively reflect the sun's energy from the roof surface, despite the color. Cool materials for low-slope roofs are mainly bright white in color, although non-white colors are starting to become available for sloped roof applications. Cool Roofs also have high emissivity, allowing them to emit infrared energy. Unfortunately bare metals and metallic coatings tend to have low emissivity and are not considered cool materials.

Cool roofs reduce the roof surface temperature by up to 100 °F, thereby reducing the heat transferred into the building below. This helps to reduce energy costs (by keeping attics and ducts cooler), improve occupant comfort, reduce maintenance costs, and increase the life cycle of the roof.

Some benefits of Cool Roofs are that they can:

- save on annual electricity bills by reducing the summer cooling load and corresponding air-conditioning costs
- save peak electricity demand costs in locations that use time-of-use metering
- reduce roof maintenance and replacement expenses by extending roof life
- increase indoor comfort in summer by reflecting heat away from the roof surface.

Figures 4 and 5 show temperature measurements from other installations on a hot summer day, before and after a cool roof treatment.

Figure 4. Roof before treatment; Thermometer reads 178 °F.

Figure 5. Dramatic decrease in roof air temperature after cool roof was installed.

Products for low-slope roofs, commonly found on commercial and industrial buildings, fall into two categories: (1) single-ply materials and (2) coatings. Single-ply materials are large sheets of pre-made roofing that are mechanically fastened over the existing roof and sealed at the seams. Coatings are applied using rollers, sprays, or brushes over an existing clean, leak-free roof surface.

Products for sloped roofs, usually found on residences, are currently available in clay or concrete tiles. These products stay cooler by the use of special pigments that reflect the sun's infrared heat. Lower priced shingles or coated metal roofing products are not yet available in "cool" versions. (The ENERGY STAR® website lists cool roof products and manufacturers, www.energystar.gov.)

If a cool roof were used, much of the sun's energy will be reflected, keeping the roof cooler. This, in turn, reduces the cooling energy required to maintain building temperatures in the summer. A slightly larger amount of energy will be required for heating; however, in the climate of West Point, the cooling savings out-weighs the extra heating energy costs.

3.1.3 Solution

Whenever replacing a building's roof, provide an outer surface that is categorized as a Cool Roof. Incorporate Cool Roof requirements into the Installation Design Guide.

3.1.4 Savings

ENERGY STAR qualified roof products save money and energy by reducing the amount of air-conditioning needed to keep a building comfortable. ENERGY STAR qualified reflective roof products can reduce peak cooling demand by 10 to 15 percent and can reduce building energy use by up to 50 percent.

Exact energy and money savings will depend on a number of factors, such as the type and efficiency of insulation in the ceilings and exterior walls; the windows; the efficiency of your cooling system; and, most importantly, the climate of the building's location. Using the Energy Star Roofing Calculator for West Point conditions showed the following for a 10,000 sq ft roof:

- office building, air-conditioned, used 7 days/wk
- existing dark roof: bitumen, white granular, reflectance 0.25
- Energy Star labeled roof: membrane, white, reflectance 0.75
- electricity savings: 8,318 kWh/yr worth $1,039
- natural gas increase: 106 therms worth $131
- net savings: $908/yr/10,000 sq ft.

Although the exact square footage of roofing at West Point that could benefit from Cool Roofs is unknown, assuming the application of this technology to 1 million sq ft of roofing would yield the following calculated savings.

3.1.5 Total savings

Savings are estimated to be: $91 k/yr.

There are no cost savings in buildings with no air-conditioning, but the cool roofs will keep them cooler and more comfortable in the summer.

3.1.6 Investments

Initial material costs are comparable with traditional roofing materials—some cool products cost less than traditional materials, some cost up to 20 percent more. Cool protective coatings can be reapplied repeatedly every 10 to 15 yrs and reduce, if not eliminate the need for expensive roof tear-offs. Combining these maintenance savings with an average 20 percent savings on air-conditioning costs make cool roofing a better bargain over the long term.

3.1.7 Payback

Simple payback will occur within 1 summer month.

3.2 BE #2: Add insulated panels behind single pane windows, Gillis Field House Building 633

3.2.1 Existing conditions

Figure 6 shows a view of the interior of Gillis Field House, Building 633, a large facility that is used for indoor track meets and other inside sporting events. It was built about 70 yrs ago and has undergone several renovations. It currently has a forced air heating and ventilating system. At each end of the building there is a group of seven windows that were once opened to ventilate the building, but which are now painted over to block sunlight and have not been used for years. This 70 sq ft of window area (per side) is not insulated and appears to be single pane glass. A single pane window offers little resistance to heat flow and their continued use is energy wasteful during all heating seasons.

3.2.2 Solution

Install insulated panels behind the existing glass windows. Place the new panels as close to the glass windows as possible to provide a small dead air space. The windows need to be inspected before the insulating panels are installed. Replace all broken windows and seal all openings and cracks between the windows, frames, and building structure.

Figure 6. Inside of Field House showing uninsulated single-pane windows in wall.

The new panels will provide a resistance to heat transfer and will consist of 2-in. of rigid fiberglass having an “R” value of 8.3. The resulting new “U” value for the panel/window combination would be approximately 0.1 Btu/sq ft/°F. It is planned to place these panels immediately behind the existing windows leaving an air space as narrow as possible.

If insulated panels are not placed behind the glass windows, this energy waste will continue.

3.2.3 Savings

The placement of the insulating panels behind the existing windows will reduce the heat loss through the windows by 70 percent. The total window area is 140 sq ft. Savings are estimated to be:

Q = (1.17 – 0.1) Btu/sq ft/ °F X 140 sq ft X (4909 degree days X 24 hrs/day)/ 0.74 heating system efficiency = 23.8 million Btu/yr

Cost Savings = 23.8 million Btu/yr X $12.39/ million Btu/yr = $295/yr

3.2.4 Investment

The estimated cost to prepare the underside of the windows and install the new insulated panels is $5/sq ft for a total cost of $700.

3.2.5 Payback

The resulting payback period for the window enhancement is 2.4 yrs.

3.3 BE #3 Install interior windows in Building 622 (Library) and in the basement of Building 685.

3.3.1 Existing conditions

Building 622 and Bldg 685 are old facilities. They were originally built with single pane windows. In the library (in the south part of Bldg 622), there are still single pane windows, which, according to the staff, makes the space cold in the winter time. Building 685 had a window replacement project a few years ago and all windows on the first and second floor were replaced with double pane windows. However, for some reason the replacement was never done in the basement. During the site visit, members of the energy team tried to close several of the old metal frame windows,

but found it impossible (Figure 7). This is very energy inefficient both in the summer when the building is air-conditioned, and in the winter when heat is exhausted through the open windows.

Install interior windows, or insulating panels, that reduce heat and cooling losses. Figure 8 shows how the insulating panels work.

Figure 7. Basement windows of Building 685 (which do not close).

3.3.2 Solution

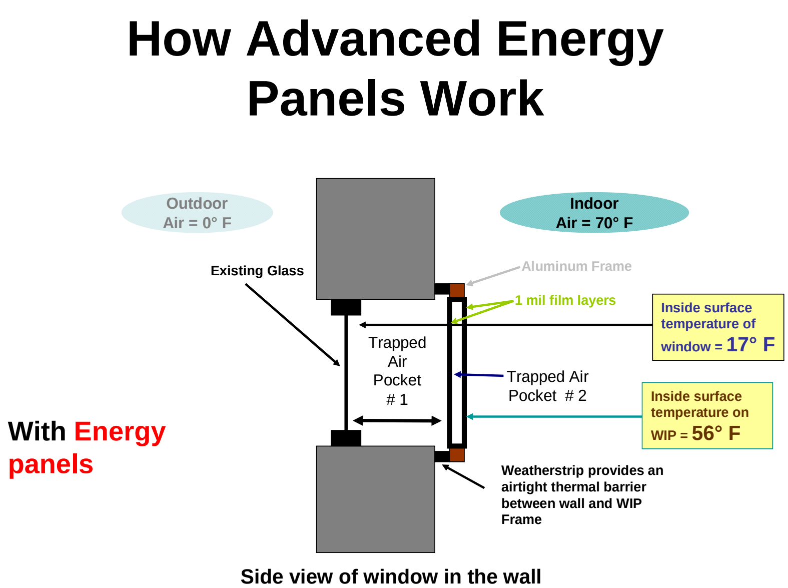

Figure 8. How advanced energy panels work.

The following positive of insulating panels are that they:

- triple insulation value
- show no loss of natural light
- can be Custom fit to *any* sized window
- have a Historic Preservation appeal.

3.3.3 Savings

Different projects on various types of buildings have shown savings up to 30 percent of total energy use of a building, depending on the size of window area that was converted, climate etc. Every building must be analyzed by itself prior to decisionmaking.

3.3.4 Investment

Installation costs vary depending on sizes, special adjustments to fit different frames and walls etc., but normally are much less expensive than replacing the entire window.

3.3.5 Payback

Normally within 4–8 yrs in climate zones similar to West Point climate.

3.3.6 Comment

Also in Bldgs 753 and 2101 there are parts that could be candidates for installing interior windows like above.

It is strongly recommended that the library staff (in Bldg 622) keep the vestibule door closed, to make sure that there is a buffer zone of mixed air between the inner spaces and outdoors. During our visit the vestibule door was locked open (Figures 9 and 10).

Figure 9. Library vestibule door.

Figure 10. Vestibule door of Building 622 (Library), held in open position.

3.4 BE #4: Insulate attic in southern part of Building 622 (Library)

3.4.1 Existing conditions and problems

The temperature in the attic was found to be around 70 °F although it was above 90 °F outside. The reasons were that the air handling unit (AHU) that is supposed to supply conditioned (cold) air to the spaces below the attic has a large hole in the connection between the AHU itself and the supply air duct (Figure 11). This allows at least 50 percent of the air supply end up in the attic.

Secondly, the insulation on top of the false ceiling is not doing its job since it is not placed properly (Figure 12). Insulation bats have been moved around, insulation leaks around light fixtures; there is no insulation above fixtures etc. This makes the attic cold in summer and warm in winter, and consequently wastes costly energy.

Figure 11. Large gap in the supply duct, Building 622, Library.

Figure 12. Improperly installed insulation above the false ceiling of Building 622 is very effective.

3.4.2 Solution

Fix the AHU so it can supply air to the spaces where people work rather than to the attic.

Insulate the false ceiling with 6 in. of mineral wool. Install sheet metal over every single light fixture, allowing some space above the fixture to prevent over-heating. Finally, add 6 in. of polyurethane foam on top of it all. This will reduce the heat and cool losses to virtually nothing (compared to the walls and windows of this around 1930s vintage building) through the false ceiling / attic.

3.4.3 Savings

The savings will come from:

1. AHU providing heated or cooled air to the premises; the air flow can probably be reduced when the supply reaches the occupants. Also the discharge air temperature has probably been set down to satisfy complaints and thus can now be raised in summer and lowered in winter. Not enough data was available to calculate the savings to be gained by fixing the AHU, but it is such a small job that simple payback would occur in a matter of weeks.

2. Reducing heat and cool losses through the attic. Add insulation to a poorly insulated ceiling. Before adding insulation, assuming an average of 0.5 in. of insulation (taking into account missing insulation, leaks through and besides fixtures:

   Annual energy loss is 1.2 W/m^2, °C * 3,313 degree-days C * 24 hrs/day = 95 kWh/m^2 of ceiling area per yr (= 30,379 BTU/sq ft).

   Adding 6 in. of mineral wool and 6 in. of foam:

   Annual energy loss is 0.1 W/m^2, °C * 3,313 degree-days C * 24 hrs/day = 8 kWh/m^2 of ceiling area per yr.

Net savings, for approximately 10,000 sq ft (= 930 m^2) then is:

930 m^2* (95 – 8 kWh/m^2) = 80.900 kWh/yr (276 MMBtus/yr) worth $3,420/yr

Using a gas price of $12.39/MMBTU and 70 percent efficiency of boiler plus distribution (from gas into the boiler and until the heat reaches the coil in the AHU) gives total costs of $4,900/yr.

3.4.4 Investments

Fixing the AHU: $500

Insulating the attic: With 10,000 sq ft of total area, costs are calculated at approximately $50,000.

3.4.5 Payback

Simple payback will occur:

- *Fixing the AHU*: Within a few weeks
- *Insulating the attic*: Within 11 yrs.

3.5 BE #5: Install foundation insulation

3.5.1 Existing conditions and problems

When most of West Point's buildings were built, it was not standard practice to insulate the building foundation. This is now standard practice and makes economic sense, especially in northern climates like West Point, given current energy costs. Buildings with foundation insulation have

smaller heating and cooling loads than buildings without foundation insulation. This should be done to the extent possible where buildings do not abut concrete sidewalks and/or driveways.

3.5.2 Current technology

Many West Point buildings are slab-on-grade construction with no slab perimeter insulation.

3.5.3 Recommended solution

Add insulation to the perimeter of buildings with slab-on-grade foundations. The insulation should cover the building perimeter from the ground floor into the ground as far as the foundation goes. This increases the insulation from R = 0 to R = 15.

3.5.4 Energy savings

FEDS calculations show that adding insulation to the buildings listed above would save 8,069 MMBtu/yr for total monetary savings of $106,901/yr.

3.5.5 Additional benefits

No O&M savings are associated with this ECM, but comfort levels will be improved for the occupants of these buildings.

3.5.6 Investment

A total of $470,233 will be required to install foundation insulation across the site where cost-effective.

3.5.7 Payback

The simple payback is 4.4 yrs.

Table 3. ECM BE-5, Insulate the perimeter of buildings with slab-on-grade foundations.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
BE_5A	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	57	6	$1,439	0	0	$–	$1,439	$12,967	9.0
BE_5B	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–1	2	$(19)	150	1855	$–	$1,836	$9,192	5.0
BE_5C	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–4	2	$(76)	83	1029	$–	$953	$4,295	4.5
BE_5D	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	1	0	$18	33	410	$–	$428	$4,279	10.0
BE_5E	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–8	5	$(163)	281	3478	$–	$3,315	$22,536	6.8
BE_5F	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–38	18	$(740)	807	10742	$–	$10,002	$41,725	4.2
BE_5G	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	0	0	$–	143	1771	$–	$1,771	$11,193	6.3
BE_5H	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–9	4	$(187)	212	2622	$–	$2,435	$18,204	7.5
BE_5I	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	0	0	$–	141	1743	$–	$1,743	$19,388	11.1
BE_5J	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	0	0	$–	155	1926	$–	$1,926	$13,099	6.8
BE_5K	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–7	8	$41	559	6921	$–	$6,962	$25,880	3.7
BE_5L	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–6	49	$1,218	3722	46121	$–	$47,339	$168,659	3.6
BE_5M	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	26	5	$951	390	4830	$–	$5,781	$49,882	8.6
BE_5N	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	5	4	$158	70	870	$–	$1,028	$8,624	8.4
BE_5O	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	0	0	$–	1307	19946	$–	$19,946	$60,310	3.0
Totals		*16*	*103*	*$2,640*	*8053*	*104264*	*$–*	*$106,904*	*$470,233*	*4.4*

3.6 BE #6: Insulate ceilings and attics

3.6.1 Existing conditions and problems

In some buildings on site, ceiling and attic insulation is inadequate. Ceiling and attic insulation is critical to reduce heat loss during the winter and solar gain from the sun during the summer.

3.6.2 Current technology

Current roof insulation systems range from no insulation to R-19.

3.6.3 Recommended solution

The amount of insulation that is appropriate to add depends on the amount of insulation that currently exists, how much the facility is heated and cooled, and what type of roof the building has. Some buildings will need insulation added to the attic (Table 4). Others will need insulation placed above the suspended ceiling (Table 5).

3.6.4 Energy savings

Adding insulation to the buildings listed above would save 48,639 MMBtu/yr according to FEDS calculations. Total monetary savings is $758,941/yr.

Additional Benefits
There are no O&M savings associated with this ECM, but comfort levels will be improved for the occupants of these buildings.

3.6.5 Investment

A total of $1,762,796 will be required to install roof, attic, and ceiling insulation across the site where cost-effective.

3.6.6 Payback

The simple payback is 2.3 yrs.

Table 4. ECM BE #6a, Install additional attic insulation.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
BE_6A	Attic Ceiling: Increase Insulation by R-13 (blow-in cellulose)	7	3	$326	0	0	$–	$326	$3,209	9.8
BE_6B	Attic Ceiling: Increase Insulation by R-13 (blow-in cellulose)	62	13	$2,519	519	6426	$–	$8,945	$78,086	8.7
BE_6C	Attic Ceiling: Increase Insulation by R-19 (blow-in cellulose)	3	4	$266	112	1383	$–	$1,649	$15,760	9.6
BE_6D	Attic Ceiling: Increase Insulation by R-30 (blow-in cellulose)	92	39	$5,314	1965	24349	$–	$29,663	$54,199	1.8
BE_6E	Attic Ceiling: Increase Insulation by R-30 (blow-in cellulose)	124	66	$7,389	2707	33544	$–	$40,933	$75,455	1.8
BE_6F	Attic Ceiling: Increase Insulation by R-30 (blow-in cellulose)	0	0	$–	1503	24996	$–	$24,996	$52,436	2.1
BE_6G	Attic Ceiling: Increase Insulation by R-30 (blow-in cellulose)	0	0	$–	1715	31407	$–	$31,407	$51,508	1.6
BE_6H	Attic Ceiling: Increase Insulation by R-30 (blow-in cellulose)	0	0	$–	3359	51287	$–	$51,287	$85,322	1.7
BE_6I	Attic Ceiling: Increase Insulation by R-30 (blow-in cellulose)	15	9	$962	406	5032	$–	$5,994	$33,465	5.6
BE_6J	Attic Ceiling: Increase Insulation by R-30 (blow-in cellulose)	83	20	$3,737	672	8323	$–	$12,060	$64,029	5.3
BE_6K	Attic Ceiling: Increase Insulation by R-30 (blow-in cellulose)	118	50	$6,233	2348	29086	$–	$35,319	$188,815	5.3
BE_6L	Attic Ceiling: Increase Insulation by R-38 (blow-in cellulose)	189	58	$9,088	2334	35326	$–	$44,414	$77,715	1.7
BE_6M	Attic Ceiling: Increase Insulation by R-38 (blow-in cellulose)	447	138	$21,628	5578	78361	$–	$99,989	$182,706	1.8
Totals		*1140*	*400*	*$57,462*	*23218*	*329520*	$–	*$386,982*	*$962,705*	*2.5*

Table 5. ECM BE #6b, Add insulation above suspended ceiling.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint	Investment	Simple Payback
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr	$/yr	$/yr	$	yrs
BE_6N	Suspended Ceiling: Increase Insulation by R-11	643	292	$18,798	0	0	$–	$18,798	$77,053	4.1
BE_6O	Suspended Ceiling: Increase Insulation by R-19	8	0	$259	480	5951	$–	$6,210	$21,544	3.5
BE_6P	Suspended Ceiling: Increase Insulation by R-19	0	0	$–	1653	20480	$–	$20,480	$60,029	2.9
BE_6Q	Suspended Ceiling: Increase Insulation by R-19	751	269	$36,446	9020	111764	$–	$148,210	$137,712	0.9
BE_6R	Suspended Ceiling: Increase Insulation by R-19	4	4	$294	265	3287	$–	$3,581	$30,623	8.6
BE_6S	Suspended Ceiling: Increase Insulation by R-19	7	2	$685	480	8789	$–	$9,474	$64,222	6.8
BE_6T	Suspended Ceiling: Increase Insulation by R-38	23	27	$1,502	1388	17194	$–	$18,696	$56,294	3.0
BE_6U	Suspended Ceiling: Increase Insulation by R-38	51	48	$4,545	1511	18724	$–	$23,269	$39,202	1.7
BE_6V	Suspended Ceiling: Increase Insulation by R-38	122	90	$7,916	3221	39910	$–	$47,826	$158,134	3.3
BE_6W	Suspended Ceiling: Increase Insulation by R-38	-54	251	$12,809	4708	62606	$–	$75,415	$155,278	2.1
Totals		*1555*	*983*	*$83,254*	*22726*	*288705*	*$–*	*$371,959*	*$800,091*	*2.2*

3.7 BE #7: Insulate metal roofs and re-roof / insulate built-up roofs

3.7.1 Existing conditions and problems

In some buildings on site, roof insulation is inadequate. Roof insulation is critical to reduce heat loss during the winter and solar gain from the sun during the summer.

3.7.2 Current technology

Current roof insulation systems range from no insulation to R-8.9.

3.7.3 Recommended solution

Insulation can be added to metal roofs from the interior (Table 6). Flat, built-up roofs are best insulated when they are replaced. However, energy saving resulting from adding the insulation means that these roofs can be replaced at any time (Table 7).

3.7.4 Energy savings

Adding insulation to the buildings listed above would save 99,393 MMBtu/yr according to FEDS calculations. Total monetary savings is $1,502,485/yr.

Additional Benefits

There are no O&M savings associated with this ECM, but comfort levels will be improved for the occupants of these buildings.

3.7.5 Investment

A total of $3,494,383 will be required to install roof, attic, and ceiling insulation across the site where cost-effective.

3.7.6 Payback

The simple payback is 2.3 yrs.

Table 6. ECM BE #7a, Insulate existing metal roof.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
BE_7A	Add Insulation to Interior Surface of Metal Roof: 4-in. Fiberglass	6620	1986	$313,768	67392	855393	$–	$1,169,161	$585,439	0.5
BE_7B	Add Insulation to Interior Surface of Metal Roof: 4-in. Fiberglass	65	48	$4,729	1275	18075	$–	$22,804	$189,117	8.3
Totals		*6685*	*2034*	*$318,497*	*68667*	*873468*	*$–*	*$1,191,965*	*$774,556*	*0.6*

Table 7. ECM BE #7b, Reroof and insulate existing built-up roof.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
BE_7C	Insulate Built-up Roof Surface (R-10) and Re-Roof		0	$–	1074	13312	$–	$13,312	$181,451	13.6
BE_7D	Insulate Built-up Roof Surface (R-10) and Re-Roof		0	$–	1204	14915	$–	$14,915	$149,417	10.0
BE_7E	Insulate Built-up Roof Surface (R-10) and Re-Roof	306	12	$10,117	3873	47990	$–	$58,107	$422,738	7.3
BE_7F	Insulate Built-up Roof Surface (R-10) and Re-Roof	0	0	$–	8275	102532	$–	$102,532	$875,814	8.5
BE_7G	Insulate Built-up Roof Surface (R-15) and Re-Roof	0	0	$–	2634	32641	$–	$32,641	$298,204	9.1
BE_7H	Insulate Built-up Roof Surface (R-15) and Re-Roof	105	67	$7,610	2378	29468	$–	$37,078	$319,168	8.6
BE_7I	Insulate Built-up Roof Surface (R-15) and Re-Roof	0	0	$–	4192	51933	$–	$51,933	$473,035	9.1
Totals		*411*	*79*	*$17,727*	*23630*	*292791*	*$–*	*$310,518*	*$2,719,827*	*8.8*

3.8 BE#8: Install wall insulation

3.8.1 Existing conditions and problems

Many buildings were built with concrete block or masonry walls, and were never insulated. This allows heat to conduct through the walls easily, forcing heating and cooling systems to work harder and/or leaving the occupants uncomfortable.

3.8.2 Current technology

Current walls are uninsulated.

3.8.3 Recommended solution

Install insulation on the interior surface of the masonry walls (Table 8). Some of the family housing and recreation buildings can benefit from blow-in insulation (Table 9). Note that this retrofit may not be applicable in the historic facilities as implementation would be problematic. The general vintage of the buildings is called out below.

Energy Savings

Adding insulation to the buildings listed above would save 16,705 MMBtu/yr according to FEDS calculations. Total monetary savings is $241,322/yr.

Additional Benefits

There are no O&M savings associated with this ECM, but comfort levels will be improved for the occupants of these buildings.

3.8.4 Investment

A total of $2,995,075 will be required to install wall insulation across the site where cost-effective.

3.8.5 Payback

The simple payback is 12.4 yrs.

Table 8. ECM BE #8a, Add insulation to interior wall surfaces.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
BE_8A	Add Interior Masonry Surface Insulation: R-12.4	1	27	$493	2935	36359	$–	$36,852	$425,449	11.5
Totals		*1*	*27*	*$493*	*2935*	*36359*	*$–*	*$36,852*	*$425,449*	*11.5*

Table 9. ECM BE #8b, Blow-in insulation to existing walls.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
BE_8B	Blow-in Wall Insulation to Fill Available Space	385	136	$17,840	8313	105507	$–	$123,347	$1,586,611	12.9
BE_8C	Blow-in Wall Insulation to Fill Available Space	19	26	$1,666	1853	28684	$–	$30,350	$353,652	11.7
BE_8D	Blow-in Wall Insulation to Fill Available Space	0	0	$–	211	3502	$–	$3,502	$46,224	13.2
BE_8E	Blow-in Wall Insulation to Fill Available Space	0	0	$–	541	9908	$–	$9,908	$98,217	9.9
BE_8F	Blow-in Wall Insulation to Fill Available Space	0	0	$–	2447	37362	$–	$37,362	$484,922	13.0
Totals		*404*	*162*	*$19,506*	*13365*	*184963*	*$–*	*$204,469*	*$2,569,626*	*12.6*

3.9 BE#9: Replace inefficient single pane metal windows

3.9.1 Existing conditions and problems

Some buildings on site are older and have their original windows still in place (single pane with metal frames), with no improvements made. This means that any damage that has occurred to the windows or other deterioration due to age has not been repaired. In addition, significant progress has been made over the years in energy efficient windows, so the energy efficiency of these older windows is greatly lacking. These buildings are heated and cooled, which means heat escapes easily in the cold months and enters easily in the hot months, both through cracks and conduction through the panes.

3.9.2 Current technology

Current windows are metal or wood framed. Bldg 655 has double pane windows. All others are single pane. It is estimated that the current U value of these windows ranges from 0.73 to 1.26.

3.9.3 Recommended solution

Replace existing single pane metal frame window systems with argon-filled double pane windows with aluminum frames and low-e coating. Some buildings should also have thermal breaks in the windows, and some need super low-e coatings. Note that this retrofit may not be applicable in the historic facilities as implementation would be problematic. The resulting U values would range from 0.32 to 0.45.

Energy Savings

For all of the building listed above, FEDS calculates an energy savings of 63,073 MBtu/yr. This equates to 910,060/yr for the various heating and cooling fuels being saved.

3.9.4 Additional Benefits

There are no O&M savings associated with this ECM, but comfort levels will be improved for the occupants of these buildings due to reduced drafts.

3.9.5 Investment

A total of 9,086,048 will be required to replace these windows.

3.9.6 Payback

The simple payback for this ECM is 10.0 yrs.

4 Central Heating Plants and Heat Distribution Systems ECMs

4.1 CEP #1: Install missing insulation in CEP and heat distribution system, repair leaks

4.1.1 Existing conditions and problems

The piping system in the CEPs and the steam and condensate system distribution lines have uninsulated pipes or valves, and leaks (Figures 13–15).

Figure 13. Uninsulated pipeline.

Figure 14. Uninsulated valves.

Table 10. ECM BE #9, Replace inefficient single pane metal windows.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
BE_9A	Install Thermal Break Aluminum Frame Double Pane Argon/Low-e Window	-6	1	$(344)	786	14391	$–	$14,047	$169,851	12.1
BE_9B	Install Thermal Break Aluminum Frame Double Pane Argon/Low-e Window	-27	5	$(717)	1074	13302	$–	$12,585	$107,073	8.5
BE_9C	Install Thermal Break Aluminum Frame Double Pane Argon/Low-e Window	0	0	$–	3782	46863	$–	$46,863	$457,834	9.8
BE_9D	Install Thermal Break Aluminum Frame Double Pane Argon/Low-e Window	0	0	$–	529	8791	$–	$8,791	$80,471	9.2
BE_9E	Install Thermal Break Aluminum Frame Double Pane Argon/Low-e Window	0	0	$–	940	17223	$–	$17,223	$134,378	7.8
BE_9F	Install Thermal Break Aluminum Frame Double Pane Argon/Super Low-e Window	63	64	$4,945	2283	28288	$–	$33,233	$340,578	10.2
BE_9G	Install Wood or Vinyl Frame Double Pane Argon/Low-e Window	521	211	$25,945	12490	158537	$–	$184,482	$1,776,524	9.6
BE_9H	Install Wood or Vinyl Frame Double Pane Argon/Low-e Window	23	53	$3,668	4332	67063	$–	$70,731	$616,872	8.7
BE_9I	Install Wood or Vinyl Frame Double Pane Argon/Low-e Window	15	55	$3,049	3377	41845	$–	$44,894	$540,818	12.0
BE_9J	Install Wood or Vinyl Frame Double Pane Argon/Low-e Window	118	54	$6,334	3177	48068	$–	$54,402	$468,299	8.6
BE_9K	Install Wood or Vinyl Frame Double Pane Argon/Low-e Window	229	237	$17,823	16128	199831	$–	$217,654	$2,342,369	10.8
BE_9L	Install Wood or Vinyl Frame Double Pane Argon/Low-e Window	227	107	$12,324	6377	89582	$–	$101,906	$924,848	9.1
BE_9M	Install Wood or Vinyl Frame Double Pane Argon/Low-e Window	0	0	$–	1742	26601	$–	$26,601	$264,946	10.0
BE_9N	Install Wood or Vinyl Frame Double Pane Argon/Super Low-e Window	60	32	$3,795	1460	18088	$–	$21,883	$259,222	11.8
BE_9O	Install Wood or Vinyl Frame Double Pane Argon/Super Low-e Window	396	90	$17,880	2977	36884	$–	$54,764	$601,965	11.0
Totals		*1619*	*909*	*$94,702*	*61454*	*815357*	*$–*	*$910,059*	*$9,086,048*	*10.0*

Figure 15. Leak in a condensate line.

4.1.2 Solutions

Install missing insulation on pipelines and valves, and repair the leaking pipes and valves. The installation of thermal insulation for a 12-in. pipe costs about $20/ft. The repair of a leaking condensate pipe in a trench costs about $500/leak.

4.1.3 Savings

The heat loss of a steam pipe without insulation is about 20,000 MBtu/ft/yr. With insulation the heat losses can be reduced to 800 MBTU/ft. Thus the savings are 19,200 MBtu/ft/yr. It is estimated that 1 percent of the pipe (or approximately 300 ft total) is without insulation.

The heat costs with efficiencies of 85 percent for steam production and 80 percent for steam distribution and a gas price at $12.39 /MMBtu are:

$12.39/MMBtu/(0.85 x 0.8) = $18.22/MMBTU

Thus the annual savings are about:

$350/ft (19.2 MMBtu/ft x $18.22/MMBtu).

The water loss per year of a leak with a diameter of 0.06 in. is about 160,000 gal.

Assuming that the makeup costs for feed water are $4/kgal the savings are $640/yr.

4.1.4 Investment

Required investments include:

- $20/ft for Insulation, or $6K for 300 ft.
- $500/leak for leak repair.

4.1.5 Payback

The payback period for installing missing thermal insulation is ~0.1 yrs.

The payback period for repairing leaks is about 0.8 yrs.

4.2 CEP #2: Gas metering for main CEP In Building 604

4.2.1 Existing conditions and problems

Gas metering in the West Point installation does not exist for the main central energy plant in Bldg 604. The gas used for the steam production can only be recalculated by the measured steam flow. As known the metering of steam flow is often inaccurate. This makes it difficult to calculate the correct gas flow of the steam boilers and the correct efficiencies of the steam production. Without accurate data, it is impossible to create an energy balance of the central energy plant and to ensure energy savings.

4.2.2 Solutions

Install missing gas metering for the CEP in Bldg 604. A gas meter station for a peak load steam production of 120 klbs/hr costs about $70K.

4.2.3 Savings

If energy savings can be verified more accurate that is a great benefit for West Point.

Assuming that 1 percent of the annual gas consumption can be saved, this saves about 40,000 MMBTU/yr, or:

40,000 MMBtu/yr x $12,39 /MMBtu = $495,600/yr

4.2.4 Payback

The payback period for installing missing gas metering is about 0.1 yrs.

4.3 CEP #3: Small boiler in CEP Building 845 (Laundry Boiler)

4.3.1 Existing conditions and problems

Figure 16 shows the Central Energy Plant in Building 845. This plant was originally built to serve only the Laundry, which is in the same building as the boilers. Today the CEP also supplies steam to the motor pool and the Hospital/School. Figure 17 shows the steam distribution net served by Building 845.

Figure 16. Central Energy Plant, Building 845.

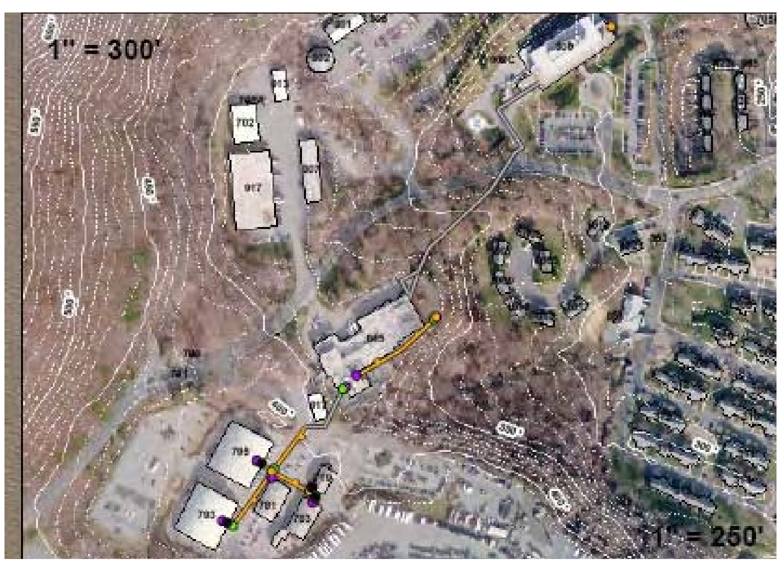

Figure 17. Steam distribution net served by Building 845.

Figure 18. Steam boiler in CEP 845.

The plant consists of two gas-fired boilers built in 1950, each with a capacity of 45,000 lbs/hr (Figure 18).

Although the boilers are old, they were running quite well according to the operational staff. Only in the summer, when the load is low, do they run at very low percentage of their capacity, resulting in low efficiencies. The summer load in 2007 was about 7,000 lbs/hr. Only the motor pool and the laundry were served in summer. The hospital runs in the summer with its own boiler. In the last few years, there was also the absorption chiller with a capacity of 400 tons in the hospital that was supplied by the steam system from CEP 845, about 8,000 lbs/hr were provided from this CEP.

4.3.2 Solutions

Overall there are three possible solutions:

1. Install a new small boiler just for the summer load.
2. Increase the summer load by bringing back the absorption chiller to the steam system.

3. Interconnect the two District Heating (DH) systems in the West Point area (see ECM CEP#6).

(This document describes only the first solution.)

A new small summer boiler with a capacity of 10,000 lbs/hr has first costs of about $800K.

4.3.3 Savings

A new small boiler has a higher efficiency than the old boiler for the summer months between May and September. It is assumed that the new boiler has an efficiency of 85 percent compared to the old boiler that has an efficiency of only 50 percent, this will reduce the gas consumption.

The daily summer load as shown in the daily log data is about 170 klbs/day. Thus the summer steam production for the 5 summer months is about:

5 x 30 days x 170 klbs/day = 25,500 klbs.

New boiler gas consumption is:

25,500 klbs x 1,08 MMBtu/klbs / 0.85 = 32,400 MMBTU

Old boiler gas consumption is:

25,500 klbs x 1,08 MMBtu/klbs / 0,50 = 55,080 MMBTU

Savings: (55,080 – 32,400) MMBTU x $12,39 / MMBTU = $281K

4.3.4 Payback

The payback period for installing a small summer boiler is about 2.9 yrs.

4.4 CEP #4: Reduce steam pressure to a standardized mid or low pressure

4.4.1 Existing conditions and problems

The main steam distribution net in the central area of West Point, supplied by CEP in Building 604, has two different pressure systems. The high pressure system operates at 160 psig (pound-force per square inch gauge)

and the low pressure system operates at 20 psig. The boiler in 604 produces high pressure steam, which is reduced with valves to low pressure Figure 19. In addition there are pressure reducing valves in the distribution system, for example in the steam line to Thayer Hotel, the pressure is reduced to 80 psig.

At each building, the high pressure steam is reduced from high pressure to mid or low pressure, depending on the end use of the steam. Figure 20 shows pressure reducing valves in Building 745A, Mess Hall.

Figure 19. Pressure reducing valves in CEP 604.

Figure 20. Pressure reducing valves in Building 745A (Mess Hall).

The problems with such a system of high, mid, and low pressures are:

- The system is complicated with parallel steam lines and many steam reducing valves, which cause high first costs and maintenance costs.
- High pressure steam lines run at high temperatures, which typically cause high heat losses. Many parallel lines increase the pipe surface area compared to one-pipe line; this also increases the heat losses.
- High pressure steam is only required for the laboratory (steam turbine), the absorption chillers, and, in peak load times, for transportation to the furthermost steam user.

4.4.2 Solutions

Convert the system to a standardized lower steam pressure. The optimal pressure has to be found in a more detailed study. It depends on the hydraulic situation and the demand of high and mid pressure steam in the buildings.

For the high pressure steam use that cannot be converted, measures for compensation have to be found. A possibility is an individual steam production, electrical or fuel, only for the real high pressure steam requirement.

The first cost for the required measures can only be calculated based on a detailed study, which was not the target of this Phase I study. However, the following assumption for first cost requirements can be used to calculate a rough estimate of the potential of this measure:

- installation of three unitary gas boilers (2,000 Mbh)

  3 x $100K = $300K
- dismounting of 10 pressure reducing valves (each $1000)

  10 x $1000 =$10K

  Total = $310K.

4.4.3 Savings

There are three main saving potentials for energy and costs:

1. Reducing the heat losses by reducing the steam temperature:
   By reducing the steam temperature from 400 °F to 300 °F, this reduces the heat losses by 30 percent. Currently, the heat losses are at least 30 per-

cent of the steam production or the gas consumption at CEP 604. A total of 9 percent (0.3 x 0.3) of the gas consumption can be saved:

0.09 x 40,000 MMBtu/yr x $12.39/MMBtu = $44,604/yr

2. Reducing maintenance cost for the pressure reducing valves

   10 x $300/yr = $3,000/yr

3. Reducing first cost requirement for replacing valves and pipelines
   Replacing one valve per year: $30,000/yr
   Replacing 300 ft per year pipeline only one pipeline instead of two parallel pipelines:

   300ft/yr x 300$/ft = $90,000/yr

Total savings: $167,600/yr

4.4.4 Payback

The payback period for reducing the steam pressure is 1.8 yrs.

4.5 CEP #5: Greater use of the backpressure steam turbine by increasing low pressure steam demand

4.5.1 Existing conditions and problems

In the CEP, (Building 604) there are two backpressure steam turbines (#2 and #3) installed. Only steam turbine #2 (Figure 21) with a capacity of 1,200 kW is used for producing electricity.

The backpressure turbine reduces the incoming 160 psig steam to 12 psig, which is used in the low pressure steam distribution system. The problem with this turbine system is that it is used only in the winter when the low pressure steam demand is high enough.

4.5.2 Solutions

Increase the low pressure steam demand in the spring and autumn to run the steam turbine more often. Note that many of the measures described in ECM CEP #4 also help to increase the low pressure steam demand. This may strengthen the case for employing the low pressure ECM.

Figure 21. Backpressure steam turbine #2 in CEP 604.

The first cost for the required measures can only be calculated based on a detailed study, which was not the target of this Phase I study. However, the following assumption for first cost requirements can be used to calculate a rough estimate of the potential of this measure:

Installation of additional 10 heat exchangers (2,000 MBH*), 10 x $24K = $240K

4.5.3 Savings

The main effect of this measure is the higher energy efficiency of a cogeneration process compared to the separate production of heat and electricity. Instead of reducing the high pressure steam with a valve, the energy is now used to produce electricity. If the steam turbine could operate 1,000 hrs/yr longer than it currently does, it would produce:

1,000 hrs/yr x 1,200 kW = 1,200 MWh/yr

West Point could realized electrical utility savings of:

1,200 MWh/yr x 125$/MWh = $150K/yr

4.5.4 Payback

The payback period for this measure is about 1.6 yrs.

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* 1 mbh = 1000 BTU/hr

4.6 CEP #6: Interconnect the north and the central heating distribution system

4.6.1 Existing conditions and problems

Figure 22 shows a map of the district heating system in West Point, which consists of the north, and the central distribution steam net systems.

The north net has a length of about 3,600 ft whereas the central net is 25,600 ft long. In the north net the steam demand is not high enough to run the boilers in Building 845 efficiently. One idea is to install a small summer boiler (see ECM CEP#3). Another problem is that the boilers in Building 845 are more than 50 yrs old and need replacement in the next years.

4.6.2 Solutions

A possible solution is to interconnect the two district heating systems with a new pipeline (Figure 23).

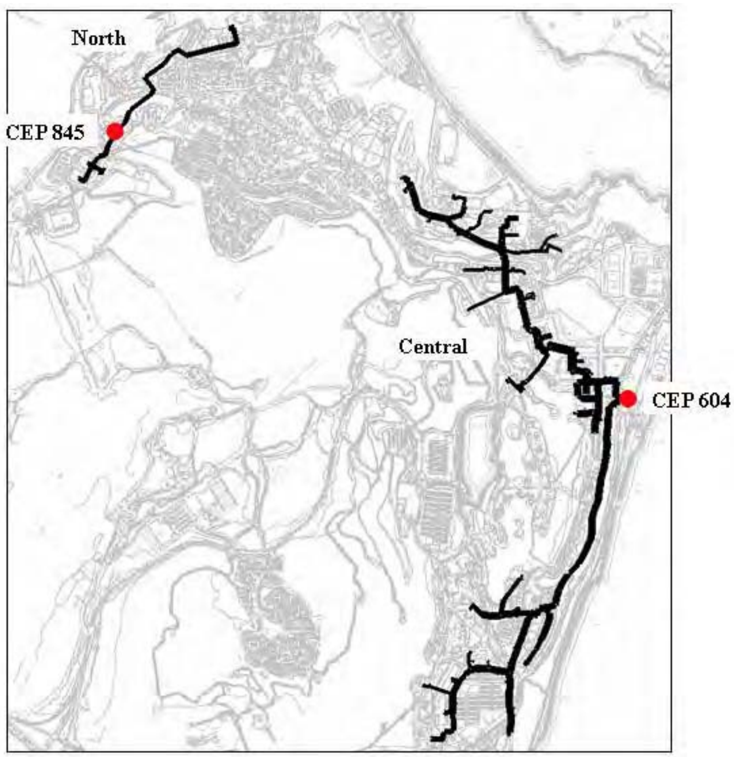

Figure 22. North and central steam distribution systems.

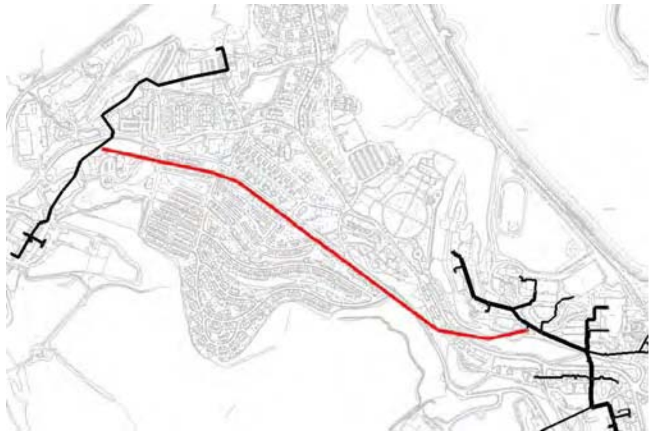

Figure 23. Pipeline interconnecting the north and central steam distribution system

The pipe length to interconnect the two systems is about 4,000 ft.

The first cost requirements for this measure depend on the heat transfer medium that is used. By converting the steam system to a low temperature hot water system (see ECM CEP #7), the first cost requirements would be significantly lower than retaining the steam system.

All these interdependencies have to be examined in a detailed study. However, a rough estimate of the potential of this measure may be calculated using the following assumptions for first cost requirements:

- hot water interconnection (8-in. pipe):
  4,000 ft x $380/ft = $1,520K
- steam interconnection (10-in. pipe):
  4,000 ft x $550/ft = $2,200K

4.6.3 Savings

The first energy saving effect is the same as described in ECM CEP #3 with a higher efficiency in the summer months for the north system.

Savings approximately $281K/yr

The second effect is that only one of the two old boilers in Building 845 must be replaced. By interconnecting the systems the back-up capacity for CEP 845 comes from CEP 604. The cost savings are the first costs of replacing the old boiler with a capacity of 45,000 lbs/hr, or $2,000K

4.6.4 Payback

The first cost requirements for this measure are:

- interconnecting pipeline: $2,200K
- savings: replacement of one boiler in 845: $2,000K
- remaining first cost: $200K.

The payback period for this measure is about 0.7 yrs.

4.7 CEP #7: Hot water conversion and replacement of unstable tunnels

4.7.1 Existing conditions and problems

Most of the existing steam distribution lines are more than 50 yrs old and at the end of their lifetime. Some parts of the central net pipelines lay in tunnels (approx. 20 percent), above ground or directly buried. The tunnels below streets are in very bad condition (Figures 24–26). The tunnels are unstable and inspections are very dangerous because the walls of the tunnels could collapse.

Figure 24. Pipeline systems in the central steam net and deteriorated condition of DH tunnels in the central system.

Figure 25. View of seriously deteriorated ceiling above central steam piping in DH tunnel.

Figure 26. Closeup view of badly deteriorated condition of DH tunnels in the central steam distribution system.

The tunnels in the central system must be replaced. The steam is responsible for a lot of problems in the district heating distribution system:

- high heat losses caused by the high temperature of the steam and the poor condition of the thermal insulation
- high condensate losses caused by corrosion in the condensate lines
- costly maintenance because of a complicated system with steam traps, pressure reduction valves, condensate pumps, etc.
- costly replacement of the old steam pipes.

4.7.2 Solutions

The solution is to convert the steam system to a low temperature hot water system with a maximum temperature of 240 °F. At this temperature level it is possible to use direct buried pre-insulated pipes, which are the most cost effective piping system currently available (Figure 27).

Inevitably, the old pipelines will eventually need to be replaced. Assuming the systems have been previously converted from steam to hot water, cheaper pre-insulated pipes could be used.

It is recommended that all the steam users be converted to hot water. In most cases, this is possible because the heat is mainly used for space heating or domestic hot water. It is estimated that less than 5 percent of the heat demand is for high temperature heat loads such as absorption chillers or cooking. Those users can be served by unitary heating systems as a substitute for the DH connection.

The hot water conversion also requires modification within the CEP for the production of hot water. If the existing steam boilers are retained, a heat exchanger will be required. The other possibility is to install hot water boilers.

Figure 27. Pre-insulated piping systems

This measure has a lot of interdependencies (production, distribution and heat users) and needs to be examined in a detailed study. For a rough estimate of the potential of this measure the following first cost assumptions can be used:

New heat exchanger at CEP 604:

130,000 MBH x $20/MBH = $2,600K

New hot water pipelines (50% of the net = 12,000 ft):

12,000 ft x $500/ft = $6,000K

New heat exchangers in the buildings:

130,000 MBH x $20/MBH = $2,600K

Some unitary boilers:

6,000 MBH x $50/MBH = $300K

Total first cost requirements: $11,500K

4.7.3 Savings

To accurately calculate the savings, it would again be necessary to consider all the difficult interdependencies in a detailed study. However, the following assumptions for the savings can be used to generate a rough estimate of the potential of this measure:

4.7.4 Reducing heat losses

Reduction of the heat losses by 60 percent, thus the gas consumption in 604 can be reduced by 18 percent (0.6 x 0.3):

0.18 x 40,000 MMBTU/yr x $12,39/MMBtu = $90K/yr

4.7.5 Reducing condensate losses

The condensate losses can be eliminated. Today the condensate losses are approximately 20 percent of the steam production:

0.2 x 300,000 klbs/yr = 60,000 klbs/yr = 961,000 cf/yr = 7,190 kgal/yr

With makeup costs for feed water at $4/kgal, the savings are $29K/yr

Reducing the maintenance costs = $240K/yr

Total annual savings = $359K/yr

Replacement of the old pipes with parallel lying high and low pressure pipelines: 18,000ft:

18,000ft x $600/ft = $10,800K

4.7.6 Payback

The first cost requirements for this measure are:

- new pipelines, heat exchangers, etc. = $11,500K
- savings from replacement of the old pipes = –$10,800K
- remaining first cost = $700K.

The payback period for this measure is about 1.9 yrs.

4.8 CEP #8: Trigeneration plant in CEP 604

4.8.1 Existing conditions and problems

All the previously mentioned problems in ECMs CEP #1 through CEP #7 show that there is an urgent need for action especially concerning the DH pipelines in the central area. In addition, with the existing backpressure steam turbine, there is potential of optimizing the cogeneration process (see ECM CEP#5).

All the solutions shown previously support the idea that the central area of West Point has potential for a trigeneration plant producing electricity, heat, and chilled water.

Only the central area of West Point has enough heating and cooling density to build up a chilled water system together with the DH system (see Figure 28).

Figure 28. Central area of West Point.

4.8.2 Solutions

The proposed solution is to install, in CEP 604, a new gas turbine and a waste heat boiler. This boiler will generate steam to drive the existing back pressure turbine #2 in winter. This first part of the suggested measure is also described in the ECSM proposal from NORESCO dated April 2005.

This ECSM proposal may be optimized by building up a central chilled water supply in CEP 604. This entails installing a new absorption chiller and a new chilled water distribution net in the central West Point area. The steam from the waste heat boiler drives the absorption chiller in summer to generate chilled water for the base load. For the peak load, there will also be electrical chillers either the existing electrical chillers in some of the buildings, depending on their age and condition, or new electrical chillers in the CEP 604. This combined generation of electricity, heating, and cooling is called a “trigeneration process.” A higher efficiency of the

whole process would be reachable if the hot water conversion (see ECM CEP #7) would be combined with the installation of the trigeneration plant. The complexity of this proposed project requires a profound and detailed study on this matter, which was not the target of Phase I study. However, the following rough estimates show only the dimensions of first cost requirements and the potential for energy and cost savings. Rough assumptions for first cost requirements are:

- new gas turbine = $20,000K
- new absorption chiller: $4,000K
- new chilled water distribution system: 6,000ft x 700$/ft = $4,200K.
- total cost = $28,200K.

4.8.3 Savings

To accurately estimate the savings, it would again e necessary to consider all the complex dependencies in a detailed study. However, for a quick overview, rough estimates for savings potential follow.

4.8.3.1 Generating electricity

The cost to run the gas turbine all year round as a base load plant would be:

5,000 kW x 8,000 hr/yr x $0.125/kWh = $5,000K/yr

The cost to run the backpressure steam turbine in winter would be:

1,200 kW x 4,000 hr/yr x $0.125/kWh = $600K/yr

4.8.3.2 Generating heat

By running the gas turbine heat is generated for DH in heating period, this amount of heat must not be generated by gas-fired boilers:

34 MBH x 4,000 hr/yr / 0.85 x $12.39/MMBtu = $1,982K/yr

4.8.3.3 Generating chilled water

By running the absorption chiller with the heat from the gas turbine during cooling season, this amount of chilled water must not be generated by electrical chillers:

34 MBH x 4,000 hr/yr x 0.7 = 95,200 MMBtu/yr

95,200 MMBtu/yr x 293 kWh/MMBtu /2.5 X $0.125/kWh = $1,395K/yr

4.8.3.4 Gas consumption

57 MBH x 8,000 hr/yr x $12.39/MMBTU = $5,650K/yr

4.8.3.5 Total annual savings ($K)

$5,000 + $600 + $1,982 + $1,395 – $5,650 = $3,327/yr

4.8.4 Payback

The payback period for this measure is about 8.5 yrs.

4.9 CEP#9: Decentralize and abandon CEP 604

4.9.1 Existing conditions and problems

CEP 604 provides steam to 65 buildings through three distribution loops. The two north loops run on a year-round basis and the south loop is shut down during the summer months. There are two gas-fired boilers with oil backup, one from is from the mid 1990s, the other from the early 2000s. They produce steam at 160 psi that is reduced outside the plant to 80 psi and heats the buildings through air handling units, radiators, or fan coil units and (in some cases) cools the buildings through absorption chillers. The distribution loops have estimated efficiencies of 46, 55, and 50 percent.

Buildings served:

- NE Loop: 601, 603, 605, 607, 609, 757
- NW Loop: 1, 100, 101, 102, 103, 105, 107, 109, 144, 146, 600, 602, 604, 606, 635, 637, 639, 655, 663, 665, 667, 671, 673, 681, 685, 687, 699, 722, 726, 727, 735, 738, 740, 745, 747, 750, 751, 753, 756, 761, 0671A, 0725A
- South Loop: 25, 28, 30, 31, 32, 34, 40, 42, 45, 48, 620, 622, 624, 626, 634, 646, 648, 674, 752.

A FEDS analysis of central plants includes the overall plant energy use calibrated to the known fuel consumption data (if available). Peripheral plant equipment energy use is estimated based on typical plant data for plants of similar size. Building energy use is calculated based on building construction and use information gathered during building audits. Loop efficiency and losses are calculated based on known piping information

and takes into account projected building-level energy use. O&M cost for central plants (if not known exactly) are estimated based on typical costs at other similar size plants.

Decentralize the CEP and install separate heating systems in each of the other buildings. Use natural gas infrared (IR) heating in areas with high ceilings and gas boilers for the admin, barracks, dining, and other recreation areas. Note that switching to high temperature hot water was not evaluated as an option (Table 12).

Table 11. FEDS analysis of central plant.

CENTRAL PLANT:			
Primary Equipment Consumption Natural Gas (therms):	4,694,626	<--FEDS Value	
Primary Equipment Consumption Distillate Oil (gallons/kWh):	241,481	<--FEDS Value	
Auxiliary Equipment Consumption Electricity (kWh)	29,779	kWh	
Total Energy Consumption (MBtu)	503,053	MBtu	
Annual Plant Output (MBtu)	425,415	MBtu	
Annual O&M Cost	107,542	<-- This is a FEDS estimate based on typical plant O&M costs.	
Marginal Value of Output ($/MBtu)	15		
Average Value of Output ($/MBtu)	15		

Loops:	604 Northwest Loop [Abandoned]		604 Northeast Loop [Abandoned]		604 South Loop [Abandoned]	
Total Delivered Energy to the Building (MBtu)	144,876	MBtu	25,853	MBtu	29,986	MBtu
Total Losses (MBtu)	173,170	MBtu	21,063	MBtu	30,467	MBtu
Total Energy Input (MBtu)	318,046	MBtu	46,916	MBtu	60,453	MBtu
Loop Efficiency (%)	46	%	55	%	50	%
Annual O&M Cost ($)	$206,056		34,048		13,294	
Abandonment Value—1st Year ($)	$2,551,822		$293,922		$420,798	

4.9.2 Recommended solution

4.9.3 Energy savings

Replacing the steam heating systems at the buildings is cost-effective. The energy savings mechanism is as follows:

- At the **building level**, energy use increases because of the added equipment in each building. Building-level energy use increased 14,298 MBTU/yr, according to FEDS calculations. This corresponds to an annual energy cost increase at the building level of $79,662/yr.
- At the **central plant,** there are savings from the distribution losses and from plant inefficiencies and operations. 224,700 MMBtu/yr are saved from the plant. This is an additional $3,339,042/yr.

4.9.4 Additional benefits

Decentralization changes maintenance costs as follows:

- At the **building level**, maintenance costs increase because of the added equipment in each building. Building-level O&M costs increase $42,519/yr.
- At the **central plant**, the annual O&M cost for the boilers and CEP equipment is eliminated saving $107,542/yr.
- **Distribution system** maintenance occurs both yearly as well as major retrofits/replacement on a periodic basis. The approximate annual value of loop O&M is $253,398/yr.

4.9.5 Investment

This decentralization will cost $3,207,715 to implement.

4.9.6 Payback

With a total savings of $3,535,259 , the simple payback is 0.9 yrs.

Table 12. Summary of Central Energy Plant ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
CEP #1	Install Missing Insulation In CEP And Heat Distribution, Repair Leaks	0	0	$–	0	$–	$–	$–	$–	–
CEP #2	Gas Metering For Main CEP In Building 604	0	0	$–	40,000	$495,600	$–	$495,600	$69,384	0.1
CEP #3	Small Boiler In CEP Building 845 (Laundry Boiler)	0	0	$–	22,680	$281,005	$–	$281,005	$800,850	2.8
CEP #4	Reduce Steam Pressure To A Standardized Mid Or Low Pressure	0	0	$–	3,600	$44,604	$3,000	$47,604	$310,000	6.5
CEP #5	Longer Use Of The Backpressure Steam Turbine By Increasing The Low Pressure Steam Demand	1,200,000	0	$150,000	0	$–	$–	$150,000	$240,000	1.6
CEP #6	Interconnect The North And The Central Heating Distribution System	0	0	$–	22,680	$281,005	$–	$281,005	$200,000	0.7
CEP #7	Hot Water Conversion And Replacement Of The Unstable Tunnels	0	0	$–	7,200	$89,208	$240,000	$329,208	$700,000	2.1
CEP #8	Trigen Plant In CEP 604	55,957,440	5,000	$7,042,747	–296,000	$(3,667,440)	$–	$3,375,307	$28,200,000	8.4
CEP #9*	Abandon CEP 604 and install heating and hot water systems in buildings	–316,046	–305	$(30,006)	289,127	$3,289,386	$275,879	$3,535,259	$3,207,715	0.9
Totals		*56,841,394*	*4,695*	*$7,162,741*	*89,287*	*$813,368*	*$518,879*	*$8,494,988*	*$33,727,949*	*4.0*

5 Domestic Water Heating Systems ECMs

5.1 SHW #1: Replace existing water heaters with high efficiency heaters

5.1.1 Existing conditions and problems

Many electric, gas, and propane water heaters that provide domestic hot water to various facilities at West Point are old and inefficient. In some cases, the equipment is not efficient in heating water for a large building.

5.1.2 Current technology

Current boilers are electric central boilers and combustion central boilers using natural gas or other fuels.

5.1.3 Recommended solution

Replace existing water heaters with more efficient gas and oil boilers. Oil boilers are recommended for buildings in the outlying installation areas. Wrap the tank with R-11 insulation, and ensure that faucet aerators and low-flow showerheads are installed in the restrooms. Installing low-flow showerheads reduces flow rate from 4.8 to 2.0 gallons per minute (gpm).

5.1.4 Energy savings

FEDS calculates that replacing these water heaters, insulating the tanks, and installing low-flow fixtures would result in an energy savings of 7,834 MMBtu/yr. Cost savings would be $189,243/yr.

5.1.5 Additional benefits

Implementing this ECM would decrease maintenance costs by $291/yr.

5.1.6 Investment

This ECM would cost $209,693.

5.1.7 Payback

With a total savings of $188,952/yr, the simple payback is 1.1 yrs.

Table 13. Summary of SHW #1: Replace existing water heaters with high efficiency heaters.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
SHW_1A	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank	1,583	55	55,531	–1,297	–16,074	$(249)	$39,208	$29,359	0.7
SHW_1B	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank	0	0	0	39	480	$(28)	$452	$3,639	8.1
SHW_1C	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank	0	0	0	1,838	22,771	$(14)	$22,757	$18,042	0.8
SHW_1D	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank	0	0	0	2,778	34,416	$133	$34,549	$20,278	0.6
SHW_1E	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank, Aerators	0	0	0	147	4,259	$(62)	$4,197	$7,526	1.8
SHW_1F	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank, LFSHs	561	0	17,424	–439	–5,434	$(116)	$11,874	$20,220	1.7
SHW_1G	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank, LFSHs	0	0	0	530	6,569	$(101)	$6,468	$10,965	1.7
SHW_1H	Replace existing water heaters with Condensing liquid petroleum gas (LPG) Boiler – 91% Combustion Efficiency, Wrap Tank, Aerators	0	0	0	190	3,488	$3	$3,491	$4,099	1.2
SHW_1I	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank, LFSHs, Aerators	858	30	29,989	–731	–9,052	$(143)	$20,794	$20,163	1.0
SHW_1J	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank, LFSHs, Aerators	0	0	0	587	7,272	$(112)	$7,160	$19,505	2.7
SHW_1K	Replace existing water heaters with Conventional Gas Boiler – 84% Combustion Efficiency, Wrap Tank	524	22	18,798	–498	–6,166	$63	$12,695	$29,961	2.4
SHW_1L	Replace existing water heaters with Conventional Distillate Oil Boiler – 86.5% Combustion Efficiency, Wrap Tank, Aerators	0	0	0	1,164	24,970	$335	$25,305	$25,936	1.0
Totals		*3,526*	*107*	*$121,742*	*4308*	*$67,499*	*$(291)*	*$188,950*	*$209,693*	*1.1*

5.2 SHW#2: Insulate water heater tank, insulate pipes near tank, lower tank temperature, install low-flow showerheads, install faucet aerators

5.2.1 Existing conditions and problems

Almost every building could use some improvement on its potable water system. Many buildings were built before the current legislation came into effect limiting maximum flow rates on end uses. Heat from potable hot water is wasted through poorly insulated or uninsulated tanks, excess of flow from faucets (2.5–3 gpm) and showerheads (3–5 gpm), and unnecessarily high setpoints (140 °F).

5.2.2 Current technology

Current technologies are natural gas and electric water heaters, natural gas central boilers, and central steam heat exchangers.

5.2.3 Recommended solution

Simple, low-cost improvements include insulating the hot water tank to R-11, installing faucet aerators to ensure a 2.0 gpm flow rate, installing low-flow showerheads for a 2.0 gpm flow rate, and turning down the tank temperature. (Water above 120 °F can burn human skin.) These measures should be installed in all buildings where not already installed.

5.2.4 Energy savings

FEDS calculations show that these miscellaneous domestic hot water retrofits would save 6,623 MMBtu/yr, for a cost savings of $162,255/yr.

5.2.5 Additional benefits

No maintenance savings are involved here, but reducing hot water temperatures to 120 °F eliminates the risk of burns from a faucet.

5.2.6 Investment

These measures would cost $116,802.

5.2.7 Payback

The simple payback is 0.7 yrs.

Table 14. Summary of SHW#2: Insulate water heater tank, insulate pipes near tank, lower tank temperature, install low-flow showerheads, install faucet aerators.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
SHW_2A	Wrap Tank with Insulation, LFSHs	0	0	0	106	1,758	$–	$1,758	$448	0.3
SHW_2B	Install Faucet Aerators	30	3	1,259	0	0	$–	$1,259	$266	0.2
SHW_2C	Wrap Tank with Insulation	0	0	0	14	236	$–	$236	$16	0.1
SHW_2D	Wrap Tank with Insulation	0	0	0	46	573	$–	$573	$134	0.2
SHW_2E	Wrap Tank with Insulation	0	0	0	71	883	$–	$883	$106	0.1
SHW_2F	Wrap Tank with Insulation, Aerators	0	0	0	110	1,822	$–	$1,822	$287	0.2
SHW_2G	Wrap Tank with Insulation, Aerators	0	0	0	33	550	$–	$550	$87	0.2
SHW_2H	Wrap Tank with Insulation, Aerators, Lower Tank Temperature	0	0	0	1	11	$–	$11	$23	2.1
SHW_2I	Wrap Tank with Insulation, Aerators, Lower Tank Temperature	0	0	0	14	169	$–	$169	$231	1.4
SHW_2J	Wrap Tank with Insulation, Insulate Pipe Near Tank, Aerators	19	2	800	0	0	$–	$800	$969	1.2
SHW_2K	Wrap Tank with Insulation, Insulate Pipe Near Tank, Aerators	10	1	452	0	0	$–	$452	$229	0.5
SHW_2L	Wrap Tank with Insulation, Insulate Pipe Near Tank, Aerators, Lower Tank Temperature	69	2	2,411	0	0	$–	$2,411	$9,185	3.8
SHW_2M	Wrap Tank with Insulation, Insulate Pipe Near Tank, Aerators, Lower Tank Temperature	63	3	2,309	0	0	$–	$2,309	$3,541	1.5
SHW_2N	Wrap Tank with Insulation, Insulate Pipe Near Tank, Aerators, Lower Tank Temperature	55	0	1,712	0	0	$–	$1,712	$6,197	3.6
SHW_2O	Wrap Tank with Insulation, Insulate Pipe Near Tank, Aerators, Lower Tank Temperature	13	1	499	0	0	$–	$499	$656	1.3
SHW_2P	Wrap Tank with Insulation, Insulate Pipe Near Tank, LFSHs, Aerators, Lower Tank Temperature	230	9	8,068	0	0	$–	$8,068	$4,644	0.6
SHW_2Q	Wrap Tank with Insulation, Insulate Pipe Near Tank, LFSHs, Aerators, Lower Tank Temperature	1329	52	46,446	0	0	$–	$46,446	$27,192	0.6
SHW_2R	Wrap Tank with Insulation, Insulate Pipe Near Tank, LFSHs, Aerators, Lower Tank Temperature	380	15	13,303	0	0	$–	$13,303	$7,876	0.6
SHW_2S	Wrap Tank with Insulation, Insulate Pipe Near Tank, LFSHs, Aerators, Lower Tank Temperature	242	10	8,464	0	0	$–	$8,464	$4,976	0.6
SHW_2T	Wrap Tank with Insulation, Insulate Pipe Near Tank, LFSHs, Aerators, Lower Tank Temperature	404	16	14,142	0	0	$–	$14,142	$8,261	0.6

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
SHW_2U	Wrap Tank with Insulation, Insulate Pipe Near Tank, LFSHs, Aerators, Lower Tank Temperature	639	25	22,371	0	0	$–	$22,371	$13,080	0.6
SHW_2V	Wrap Tank with Insulation, LFSHs, Aerators, Lower Tank Temperature	0	0	0	120	1,492	$–	$1,492	$1,223	0.8
SHW_2W	Wrap Tank with Insulation, LFSHs, Lower Tank Temperature	0	0	0	381	4,723	$–	$4,723	$5,097	1.1
SHW_2X	Wrap Tank with Insulation, LFSHs, Lower Tank Temperature	0	0	0	562	6,963	$–	$6,963	$5,284	0.8
SHW_2Y	Wrap Tank with Insulation, LFSHs, Lower Tank Temperature	0	0	0	1,596	19,772	$–	$19,772	$15,640	0.8
SHW_2Z	Wrap Tank with Insulation, LFSHs, Lower Tank Temperature	0	0	0	86	1,069	$–	$1,069	$1,154	1.1
Totals		*3483*	*139*	*$122,236*	*3140*	*$40,021*	*$–*	*$162,257*	*$116,802*	*0.7*

6 Renewables and Water Conservation ECMs

6.1 REN #1: Barracks shower hot water heat recovery

6.1.1 Existing conditions

In the barracks, there are two water high use periods that occur when the Cadets are taking showers. The first is late afternoon after their athletic training activities. The other period is in the late evening before going to bed. During these times, there is a high energy use for heating the domestic hot water that is used in taking the showers. Steam to hot water heat exchangers are used for this purpose. Currently the warm shower water is collected and drained away using the sewer drainage system. There is no attempt to recover any heat from this waste steam.

All shower rooms are centrally located adjacent to several Cadet rooms. In the newer barracks buildings the showers serve the occupants of 10 to 20 rooms each. These are barracks Buildings numbered 738, 740, 745 C, 745 D&E, 751, and 756. In barracks numbered 602 and 735 the shower rooms are smaller serving approximately four rooms each. This ECM is applied to the barracks that have the larger shower rooms. However, Barracks Building 756 was chosen to illustrate the economics.

6.1.2 Solution

Heat can be recovered from the sewer drainage system during the time periods when showers are occurring. This energy could then be used to preheat the cold water entering the hot water heaters. This can be accomplished by installing a shower drain heat recovery unit, which consists of a copper tube wound around the shower drain line for about 8 ft in length. Figure 29 shows this heat recovery unit. The installation of this heat exchanger requires replumbing of the building's cold water line before it enters the hot water heaters in the basement. The cold water supply pipe to the heat exchanger will be warmed reducing the steam demand to heat the hot water.

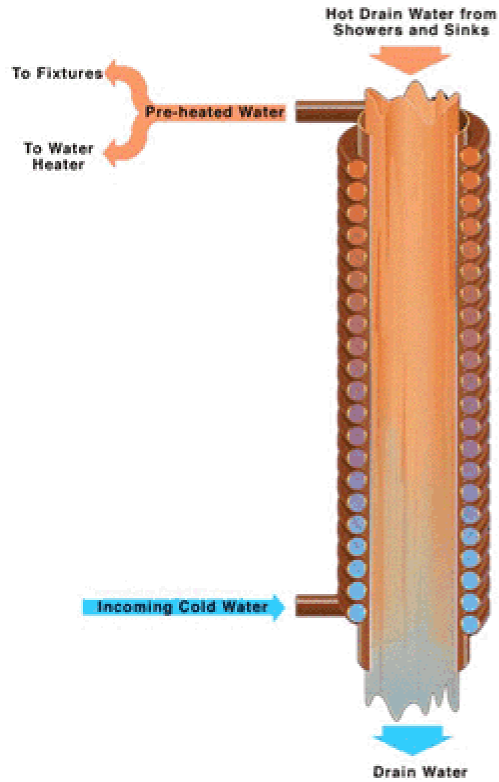

Figure 29. Shower drain heat recovery unit.

If this hot water heat recovery unit is not installed in the barracks, continued energy waste is expected and useful energy not captured.

6.1.3 Savings

It is estimated every Cadet takes an average of 1½, 5-minute showers each day. The temperature rise of the hot water is from 60 °F to 140 °F or an 80 °F temperature rise. The population in the barracks is 216 people. The heat recovery unit will save 25 percent:

Q = 862 people X 1.5 X 7days/wk X 45wks/yr X 5 min X 1.5 gal/min X 80 °F
X 8.3 lb/gal X 0.25 /.74 heating eff. = 685 million Btu/yr

Energy cost savings = 685 million Btu/yr x $12.39/million Btu = $8,490/yr

6.1.4 Investments

There are four shower rooms on each floor. The building is six floors high and the shower rooms are placed one above another. Each vertical group of showers has a common vertical drain that drops to the basement where the drains are collected and run horizontal to the outside. Since this is a

retrofit project it will be best to apply the pipe wrap around drain heat recovery unit to the 4-in. basement horizontal run of each shower group before the main sewer drain. This application is not as efficient as a vertical drop installation so two 4-in. heat recovery units will be applied to each shower group. The estimated cost to install these heat recovery units on a 4-in. drain is $2,000/drain. Building 756 has four shower group drains, which bring the heat exchanger cost to $8,000. A cold water pipe that runs to the domestic hot water heater from these heat exchangers will be required. The cost of this pipe with valves and insulation is approximately $27,000. This brings the total cost to $35,000. The estimated cost for the seven barracks buildings is $245,000.

6.1.5 Payback

The resulting simple payback for Building 756 is 4.1 yrs.

If this project is expanded to all similar barracks the estimated energy savings is 2,700 million Btu/yr for a cost savings of $34,000. The payback for all barracks is estimated to be 7.3 yrs.

6.2 WATER #1: Domestic Water Cooling Waste

6.2.1 Existing conditions

There are several water chillers in different buildings with cooling towers. Some cooling towers leak water onto the roof, some causing leaks to the rooms below (Bldg 606).

In Bartlett Hall (Bldg 753) the absorption chillers are not running, cooling energy is produced in the library building next door. The cooling towers on top of Bldg 753 are not being used. However, there is water leaking from the towers in a constant flow into the roof drain. The tower makeup water valve or pipe leaks allow fresh water to infiltrate.

In Taylor Hall (Bldg 600), 10–15 package air-conditioners are ducted to serve the different rooms. The package units have different capacities, typically with a cooling capacity of 75 kW and compressor power input of 20 kW. All the units are water cooled by domestic water. The cooling is on all the time between June and October (5 months).

6.2.2 Solution

Eliminate leaks in cooling towers. If the towers on Bldg 753 are not needed, the cooling towers should be emptied and shut off to eliminate unnecessary water use.

In Taylor Hall the package units are maybe 10–15 yrs old. When they will need to be replaced, a central cooling system should be built. The new system could be based on package units with a common condensing circuit or on fan coils connected to a chilled water system. Installing a condensing network for the existing package units may be difficult, but in connection with a major retrofit of the rooms or renewal of the units, it is possible.

6.2.3 Savings

Savings from eliminating cooling tower leaks are estimated in the following way:

- The estimated leak for 753 cooling tower is:
  10 m^3/min = 2.6 gal/min
- If the leak goes on for all cooling season (5 months), the wasted amount of water is:
  14 m^3/day = 3,700 gal/day = 2,100 m^3 = 554,800 gal/yr.

At a water cost of \$0.448/m^3, the yearly saving is \$940/yr.

Savings from installing a condensing network for the package units are estimated as follows:

- cooling capacity 75 kW, compressor power input 20 kW.
- estimated average condensing capacity during summer months 50 kW (50 percent load).
- condensing water temperature difference estimated to be 30 °C.
- average condensing water flow per unit 0.4 dm^3/s = 24 dm≥/min = 34 m^3/day = 900 gal/day
- total water usage for 15 units during a summer about 75,000 m^3/summer = 19,000 Mgal/yr.

At a water cost of \$0.448/m^3, the yearly saving in water is \$33,600/yr.

6.2.4 Investments

Eliminating the leaks in the existing towers is a measure in ordinary facility maintenance, good housekeeping; no investment is required.

The cost for eliminating the domestic cold water cooling has been estimated based on the centralized condensing network cost, i.e., connecting the existing package units into a closed condensing loop with a closed liquid cooler on the roof.

Condenser water piping or chilled water piping cost per floor area of building is $10/m^3.

The floor area of Taylor Hall is 82,567 sq ft = 7,670 m^3.

The cost estimate for centralized condenser/liquid cooler of 1400 kW and controls is $70,000.

The total cost estimate is $140,000.

6.2.5 Payback

The condenser / liquid cooler with fans and the closed circuit pumps will use electricity. The estimated electricity cost is 10 MWh/yr = $1,250

The investment payback time is $140,000 / $(33,600 – 1,250)/yr = 4.2 yrs

Eliminating the leaks in the towers has immediate payback time.

7 Controls (Building and Centralized Utility Monitoring and Control System [UMCS]) ECMs

7.1 CON #1: Increase/decrease space temperature setpoints and make them uniform

7.1.1 Existing conditions and problems

Throughout the installation, a large variation of actual space temperatures and space temperature setpoints was found. The lowest space temperatures (65 °F) were found in the ball room, Eisenhower Hall, Bldg 655. Equal conditions were also found in the Subway restaurant, old PX, Bldg 683. The setpoint in all these buildings was 55 °F, forcing the chillers to work unnecessarily more than needed. Other buildings had setpoints at different areas above 55 °F. Many buildings are air-conditioned and the systems were operating at capacity just to keep these very low indoor temperatures. This is a very energy consuming condition.

7.1.2 Solution

Develop and implement a post policy, signed by the West Point garrison commander, that the lowest acceptable space temperature setpoint during the cooling season is 76 °F and for the heating season the allowed space temperature should be no more than 70 °F. At the same time, make sure that these setpoints are included in the Installation Design Guide for all new projects and also for all future renovation/modernization projects. Lock all thermostats in secure cages, where only the respective building managers have the key. This means taking the controls out of control from the individuals working in the building. In buildings that are connected to the Energy Management Control System (EMCS), update all setpoints to match the new limits from the Garrison Commander's policy.

7.1.3 Savings

The savings by lowering the temperature setpoints will be calculated on a per square foot basis and at this stage only for the cooling season:

- Assume: 10,000 sq ft building with 10 ft ceiling, (100,000 cu ft volume), air supply 10,000 cfm and with 30% outdoor air, 3,000 cfm (=1.42 m^3/s).
- Increase space temperature (and also Supply Air temperature) by 10 °F (5.5 °C). Chiller coefficient of performance (COP) = 3.0
- Cooling savings air handling unit:
  1.42 m^3/s * 1.2 kJ/kg, °C * 1.0 kg/m^3 * 5.5 °C * 26 wks * 168 hrs / 3.0 = 13,650 kWh worth $1.7 k.
- Cooling savings from reduced transmission losses and infiltration vary according to building design, construction, and installation quality and, on average, can be assumed to be at least as high as the savings from the AHU (another $1,700).
- Total savings is approximately $3.4 k/yr, or 3.4 cents/sq ft/yr.

Heating savings are not calculated or estimated, but add to the total savings when reducing the maximum setpoints to 70 °F. Heating savings were not calculated due to a lack of knowledge of how the buildings are operated at winter time, which setpoints that are used etc.

Assuming that this ECM can be applied to at least 1 million sq ft at West Point, total savings equals $340k/yr.

7.1.4 Investment

Not more than $1,000 for a 10,000 sq ft building, all of which relates to locking thermostats; for 1 million sq ft: $100k.

7.1.5 Payback

Simple payback will occur within 2 summer months.

7.2 CON #2: Reduce HVAC run time / Schedule AHUs to match building occupancy

7.2.1 Existing conditions and problems

Most AHUs at West Point are scheduled to operate 24/7 or close to that. This is not necessary since most buildings at West Point are normally not used more than 8–12 hrs/day, 5 days/wk. Some secure areas may run for longer periods, but not continuously in most cases. West Point runs AHUs for more hours than necessary, which results in energy wasted for heating, cooling, and running fan motors.

Buildings that were noticed to have far longer operating hours than necessary could be easily identified by looking at time schedules in the EMCS system or by physical inspection in buildings where EMCS is not installed. In buildings with time clocks for AHUs, the clocks either do not operate anymore, because they were not maintained or replaced when they stopped functioning, or the AHU control switch was set to “Manual,” or, translated to EMCS time schedule language: “Always ON.”

During the assessment, it was mentioned that one reason for not switching AHUs off at nights and weekends was that janitors work at night cleaning the buildings. (Nevertheless, no person working during “unoccupied” hours in any of the West Point buildings will suffer from any lack of oxygen or risk encountering any other health related problems if the AHUs are switched OFF.)

7.2.2 Solution

In buildings where EMCS is not yet installed, install programmable timers with weekly schedules. Make sure that the timers are checked and maintained regularly and program for operating hours matching building occupancy. Once AHUs are connected to the EMCS, start using the time schedule module in the EMCS software.

7.2.3 Savings

Savings will accrue from reducing the running hours for an air handling unit with normal functions, i.e., when everything works as it is intended to (after fixing malfunctioning equipment), from 168 hrs/wk (24/7) to 60

hrs/wk (12/5), with 20,000 cfms, 30 percent outdoor air in both winter and summer for economizing reasons, and with a 10 hp supply air fan and 8 hp return air fan, the savings can be calculated as:

- heat savings, West Point climate:
  5964 heating degree days °F = 3313 degree days C): 267 MWh/yr (911 MMBtus/yr), $16.1 k/yr with 70 % boiler, plus heat distribution system efficiency (1,301 MMBtus gross) (30 % outdoor air [OA] = 6,000 cfm = 2.8 m^3/s).
- heating Distribution:
  2.8 m^3/s * 1.2 kJ/kg, °C * 1.0 kg/m^3 * 3,313 degree-days * 24 hrs/day = 267,200 kWh). The gas price = 12.39 $/MMBTu.
- cooling savings: West Point climate:
  754 cooling degree days °F = 419 degree days C): 11 MWh electricity/yr, $1.4k/yr at a blended electricity price of 12.5 cents/kWh (COP = 3.0). (Cooling: 2.8 m^3/s * 1.2 kJ/kg, °C * 1.0 kg/m^3 * 419 degree-days * 24 hrs /3.0 (=COP) =11,300 kWh.

Consequently, the annual costs for running boilers and chillers are $16.7 k.

Additionally, motor savings are calculated as:

(10 + 8 hp) * 0.746 kW/hp* (168 – 60 hrs) * 52 wks = 75 MWh/yr, $9.4 k/yr

Therefore, total savings equals $26.9 k/yr

In addition, maintenance costs can be significantly reduced due to reduced annual operational hours. Periodic maintenance such as filter replacement need not be done quite as often, etc.

From our findings at West Point, regarding AHUs running 24/7, it is safe to say that this ECM can be extrapolated to at least the equivalent of 20 units at 20,000 cfm each, thus generating total savings of $540K/yr.

7.2.4 Investment

The investments are moderate or very low:

- in buildings not connected to EMCS: New programmable timers, $2,000/20,000 cfm unit.
- in buildings attached to EMCS: No additional investment is needed.
- for 20 AHUs on average: $1,000/AHU or $20 k in total.

7.2.5 Payback

Simple payback will occur within less than 1 month

7.3 CON #3: Improved temperature control in kitchen, Building 745

7.3.1 Existing conditions

In the kitchen area of the main dining hall, space temperatures were observed to be in the range of 63 to 65 °F. It was noted this space is often cold for the occupants and nearby ovens are energized and their doors left open to bring heat into the space for improved comfort. This causes the ovens to be over worked increasing their required maintenance. The HVAC systems for the kitchen are connected to the site EMCS system, which is used to control the heating and cooling units. A review of the units' setpoints showed a temperature of 72 °F, but the return air was showing a 71 °F temperature. Obviously the unit controls need calibration and setpoints set up so as to maintain proper temperatures in the kitchen areas.

7.3.2 Solution

Maintenance and calibration are needed on the kitchen's HVAC control system. The EMCS needs to be able to accurately sense space temperatures in this space and control to a temperature of approximately 72 °F, which is a comfortable level for the kitchen's occupants.

If the controls for the kitchen's HVAC system are not recalibrated, spaces will remain ultra cool and the heating and cooling energy waste will continue. A complete evaluation of the kitchen's HVAC and other systems is recommended to identify other opportunities for cost savings.

7.3.3 Energy savings

In this kitchen area approximately three hood recovery units service the space. The total supply air handled by these units is 37,800 cu ft/minute (cfm). It is estimated the supply air from these units could be raised by 5 °F for a more comfortable temperature:

Extra cooling = 1.08 X 37,800 cfm X 5 °F X 10 hrs/day X 150 days/yr = 306 million Btuh/yr

Cooling Energy Used = 306 million Btuh/12000 Btuh/ton hr X 1 kWh/ton hr = 25,500 kWh/yr

25,500 kWh/yr X $0.125/kWh = $3,190/yr

The oven heat to overcome the coldness is approximately the same as the excess cooling:

Heating energy use = 306 million Btuh/yr / 0.8 oven efficiency = 383 million Btuh/yr

383 million Btuh/yr X $12.39/million Btu = $4,745/ yr

Total cost savings is $7,935/yr

This ECM should also improve the comfort in the spaces served.

7.3.4 Investment

A control system survey and recalibration are estimated as one-person week (40 hrs at $50/ hr = $2,000). Replacement of control devices would be more. An allowance of $3,000 is provided for the estimate. Thus the total estimated cost is $5,000.

7.3.5 Payback

The resulting payback period is 0.6 yrs:

$5,000/ $7,935/yr = 0.6 yrs

7.4 CON #4: Keller Army Hospital (KAH) AHUs retrofit and controls

The AHUs at KAH, Bldg 900, also run 24/7. They use 100 percent outdoor air (OA). (This is not completely necessary for all parts of the hospital)

For KAH, it is proposed to add ductwork so that part of 4th floor (with occasional overnight patients), radiology and the Emergency Room (at 1st floor) can be supplied with conditioned air at all times (24/7). Shut down all other AHUs whenever the other parts of the building are unoccupied. Normal occupancy is from 7.30 a.m. to 4.30 p.m. Mon – Fri.

Building drawings indicated that the total air flow from the AHUs is around 140,000 cfms, running 24/7 and at 100 percent OA. (A rough calculation was done based on the assumption that the AHUs run 140,000 cfms Mon – Fri 7.30 a.m. to 4.30 p.m. and on all other times only 30,000

cfms, still at 100 percent OA.) Supply air fans sum up to 200 hp and return air fans to 65 hp. Assume saving 130 hp fan motor power during unoccupied hours.

7.4.1 Savings

Heating Reduce air flow by 110,000 cfm (52 m^3/s) during 168 – 45 = 123 hrs/wk or an average of 17.5 hrs/day for 7 days/wk:

Savings = 52 m^3/s * 1.2 kJ/kg, °C * 1.0 kg/m^3 * 3,313 degree-days C * 17.5 hrs/day = 3,620,000 kWh = 12,350 MMBtus/yr net. With 70% boiler efficiency the gas use comes to 12,350/0.7 = 17,600 MMBtus/yr worth $218k. (Gas price = 12.39 $/MMBtu.)

Cooling: 52 m^3/s * 1.2 kJ/kg, °C * 1.0 kg/m^3 * 419 degree-days * 17.5 hrs /3.0 (=COP) =152,000 kWh worth, $19 k/yr.

Motor: Approximately a total 0f 130 hp of motors running unnecessarily: 130 hp * 0.746 kW/hp* (168 – 45 hrs) * 52 wks = 620 MWh/yr, $78 k/yr.

The total savings then equate to $315 K/yr.

By also shifting to CO_2 control for indoor air quality control during occupied hours, see ECM # HVAC-11, additional savings is achievable at KAH.

7.4.2 Investment

It is estimated that the necessary ductwork additions, including dampers and controls, will not exceed a cost limit of $200k. The successful performance of the system also assumes that all VFDs are functional, this is to ensure that the air flows are kept within limits; also see ECM # C-4.

7.4.3 Payback

Simple payback will occur within 8 months.

7.5 CON #5: Improve use of VFDs and repair/replace malfunctioning VFDs

7.5.1 Existing conditions and problems

During the assessment, it was noted that some VFDs did not work as intended and that some did not work at all. One example was from Eisen-

hower Hall (Bldg 655) where the variable frequency drive (VFD) for AHU-06 was continuously searching for an operational point that it could not find. Another example is a VFD at the KAH mechanical room in the basement (AHU-3) that is not connected or just not being used since it runs at constant full speed, 60 Hz.

7.5.2 Solution

Make sure that installed VFDs are being used for control purposes. Search for faulty sensors (e.g., pressure sensors) or other facts that disable the proper use of the VFD. If a fan or a pump is supposed to run at 60 Hz, remove the VFD and use it at some other location and function to gain efficiency.

7.5.3 Savings

Although this is not easily calculated, the following example can illustrate potential savings:

- A 60 hp supply fan motor runs constantly at full load, 60 Hz instead of being modulated by the VFD to run on the average at 30 Hz. Assume that ECM CON #2 has been performed so that the operating hours now are 60 hrs/wk instead of the normal 24/7 operation. 30 Hz operation means 15 hp instead of 60 kW.
- Energy savings:

  (60 – 15 hp) * 0.746 kW/hp * 60 hrs/wk * 52 wks = 105,000 kWh/yr. At 12.5 cents/kWh the value of using the VFD in this case would be 105,000 * 0.125 = $13,125 annually.

7.5.4 Investment

Required investment depends on the cause of the problem and the action needed to correct it. In most cases, it is believed that the investment will not exceed $5,000.

7.5.5 Payback

Simple payback will occur within 4 months for the example described above.

7.5.6 Comment

It is proposed that this ECM be performed in combination with CON#2

7.6 CON #6: Remove pneumatic thermostats from spaces with direct digital control (DDC) controls

7.6.1 Existing conditions and problems

There are still some pneumatic thermostats in use in buildings/spaces that have not been converted to DDC controls. Pneumatic and modern thermostats co-exist, side by side, and it is not known whether both still operate and, if so, which one has precedence. One example can be found in the ballroom in Eisenhower Hall where a pneumatic thermostat, still functional, with a 55 °F setpoint, is located; a new temperature sensor is located adjacent to it.

7.6.2 Solution

Remove all the pneumatic thermostats. Switch OFF the compressors still in use that pressurize the pneumatic system.

7.6.3 Savings

Savings come from a correct temperature control (which might not be the case if the pneumatics still are functional in buildings / spaces with DDC) and from not having to run the air compressors anymore.

Assuming a 2 hp compressor, 50 percent loaded to maintain system pressure, savings by switching it OFF are calculated as:

2 hp * 0.746 kW/hp * 0.5 * 8760 hrs/yr = 6,500 kWh/yr, savings of $800/yr.

7.6.4 Investment

The required investment is $500/building. (This is labor cost only since DDC controls already exist.)

7.6.5 Payback

Simple payback will occur within 8 months.

7.6.6 Comment

The 2 hp compressor assumption above might be too low; in the mechanical room in Bldg 655, there are two 5 hp compressors that are used for the pneumatics system. Thus the savings by switching OFF are higher and the payback time shorter.

7.7 CON #7: Connect more mechanical equipment to EMCS

7.7.1 Existing conditions and problems

West Point has an EMCS with the main operator terminals located in Bldg 604, the main energy plant. The EMCS is a Williams Electric system covering a total of 56 buildings around the West Point grounds. Thirteen of the buildings have recently been converted to new Honeywell software with faster and more direct communication.

Although the EMCS is apparently not used to its full potential (see ECM CON #2 regarding matching AHU operation with building occupancy, C-1b regarding temperature setback etc.) there is no reason not to expand the system and to provide more functions and more control from this system. The following systems that could easily be included into the EMCS controlling mode and thus provide more savings:

1. PX (Building 1204): RTUs that at present run only controlled by individual thermostats
2. The boiler in the basement of Bldg 687 runs 24/7. Building 687 contains the Cadet Uniform manufacturing and they use steam, but only during daytime, Mon – Fri 7 a.m. to 3:45 p.m. Having this boiler controlled (i.e., switched on and off) by the EMCS would reduce energy use by at least 20 percent, based on annual total energy use in the building.
3. Several areas with lights could also be controlled and supervised by using the EMCS (e.g., Shea Stadium, Gillis Field, entrance lights and Basketball court lights in Bldg 714, etc.).

7.7.2 Solution

Connect more buildings and systems to the EMCS. Reduce the dependency on local timers, on local controls, and on people by installing new DDC controls, automated time controls and startup sequences, etc.

7.7.3 Savings

Although savings are not easily calculated at this stage, but should be substantial.

7.7.4 Investment

An incremental investment in a system that already exists in its essential parts is not that expensive and gives good value for money.

7.7.5 Payback

Simple payback will occur within 2 to 3 yrs for this kind of incremental investment, on average. Some investments, like controlling the boiler in 687, will have a very short payback period.

7.8 CON #8: Initiate night/weekend and summer/winter setpoint changes

7.8.1 Existing conditions and problems

Similar to the case with AHUs running 24/7 at West Point, systems were observed that were not using EMCS properly, or that were not connected to the EMCS. The most promising measure is to change the setpoints for space temperature during unoccupied hours, primarily nights and weekends. Since these opportunities are not used, the buildings at West Point use more energy (for heating and cooling) than necessary. (See CON #1.)

7.8.2 Solution

During the heating season, reduce the space temperature during unoccupied hours, to save energy. As an example, Fort Drum, NY provided (and uses) the setback curve in Figure 30.

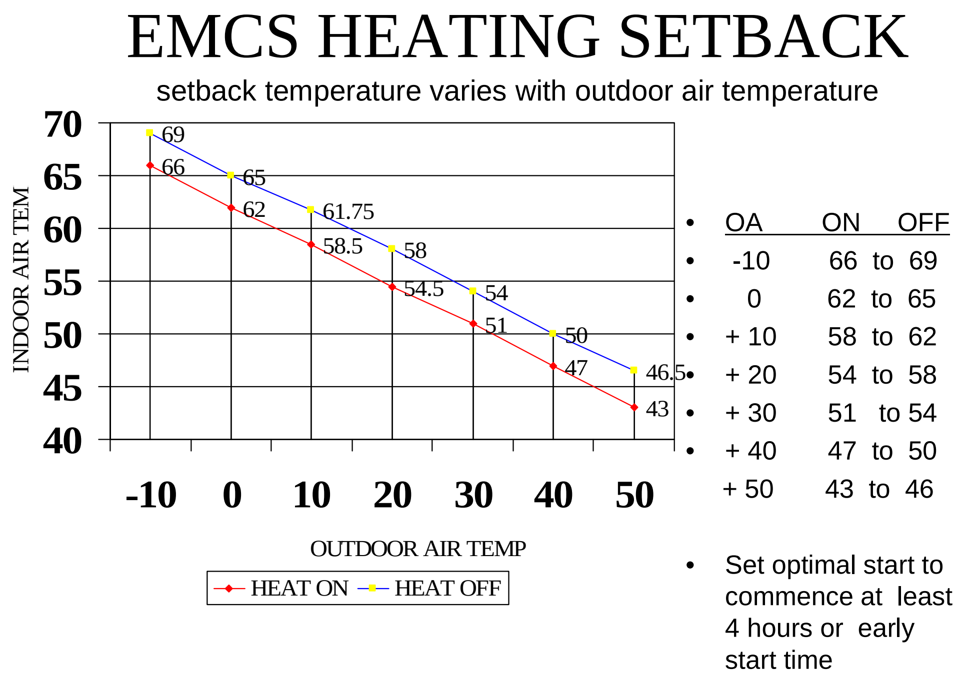

Figure 30. Example of space temperature reset schedule based on outdoor air temperature (from Fort Drum, NY).

If this curve, which sets different setback temperatures related to the actual outdoor temperature, is implemented at nights and weekends at West Point, it is believed that substantial energy savings can be achieved. A setback temperature that varies by outdoor air temperature will help to avoid the problem of freezing coils.

For the summer period, when air-conditioning is the major energy consumer, it is recommended that the setpoint is set to around 80 °F during the major time of the unoccupied hours. For comfort reasons, as in the case above with the heating season, early start-up after nights and weekends is recommended to minimize complaints from building occupants.

7.8.3 Savings

It is assumed that the recommended adjustment of AHU operation to match building occupancy has been done, ECM # C-3 (otherwise the savings by temperature setback will be much higher than shown here). This means that the savings come from reduced transmission losses and reduced losses due to infiltration in leaky buildings.

A reduction of the indoor air temperature by 3.5 °F on average would reduce the heating and cooling costs by approximately 15 percent on a full time reduction. In this case, assuming ECM CON #2 has been done, the savings will still be in the range of 5 percent of the energy needed annually to heat and air-condition buildings.

7.8.4 Investment

No investment is needed. This can be done using the functions in the EMCS. Existing staff can do the job.

7.8.5 Payback

Payback will be immediate.

7.9 CON #9: Fix failed controls in Main Post Exchange (PX), Building 1204

7.9.1 Existing conditions and problems

There is a general need to re-commission building controls and HVAC equipment throughout West Point. However, the circumstances at the PX, Bldg 1204 are unique and urgent; they need to be addressed separately to prioritize the need to get these controls fixed.

The PX building was constructed in the year 2000. The building has 17 rooftop AHUs. These are placed on the external roof, which is very hot since it is black in color (see also ECM BE #1, Cool Roofs). During the summer of 2006 the roof temperature reached 165 ˚F and this temperature was higher than the Honeywell controls (located on the AHUs) could handle so the controls failed. Since then, every individual AHU is controlled by a thermostat located down in the PX shopping area. The setpoints are not uniform (see also CON #1) and the AHUs run 24/7. The PX Hours of Operation are Mon – Wed and Fri 10 a.m. to 7 p.m., Thu 10 a.m. to 8 p.m., Sat 9 a.m. to 7 p.m. and Sun 10 a.m. to 6 p.m. The total number of opening hours then is 64 hrs. And the AHUs run 168 hrs/wk (cooling or heating unnecessarily). AHUs could be started 1 hr before opening time and shut down half an hour before closing time.

7.9.2 Other problems with the building

Air intakes right at roof level with very high outside air temperatures (black roof) makes cooling unnecessarily costly. Air intake filters not cleaned or replaced for lack of maintenance (Figure 31) makes air flow lower than designed (but this saves energy). Dampers stuck in closed positions (Figure 32) also reduce the air flow.

Figure 31. Filters in rooftop air handlers not properly maintained.

Figure 32. Fixed outside air damper.

7.9.3 Solution

The best solution is to connect the PX to the EMCS, but *only* if West Point decides to start using the system as designed to control systems operation, time scheduling, setpoint controls etc. Otherwise, programmable thermostats should be installed using fixed and uniform setpoints and time schedule programmed to match building Hours of Operation.

7.9.4 Savings

Running all the AHUs at minimum outside air flow during 104 hrs more than necessary per week, approximately 15 hrs/day (168 hrs/wk–64 hrs of operation per week), gives the following ***wasted*** energy use for heating, see also detailed calculations under the CON #2 proposal above:

16 AHUs total min OA: 25,200 cfm = 12 m^3/s

Heating: 12 m^3/s * 1.2 kJ/kg, °C * 1.0 kg/m^3 * 3,313 degree-days C * 15 hrs/day = 715,000 kWh = 2,450 MMBtus/yr net.

With 70% boiler efficiency the gas use comes to 2,450/0.7 = 3,500 MMBtus/yr worth $43k/yr.

Gas price = $12.39/MMBtu.

Cooling: 12 m^3/s * 1.2 kJ/kg, °C * 1.0 kg/m^3 * 419 degree-days * 15 hrs /3.0 (=COP) =30,000 kWh worth $3.75 k/yr.

Motor: approximately a total of 40 hp of motors running unnecessarily: 40 hp * 0.746 kW/hp* (168 – 64 hrs) * 52 wks = 160 MWh/yr, $20 k/yr

Total savings equate to $67k/yr by fixing the time schedules alone. Uniform space temperatures and setpoints will give additional savings.

7.9.5 Observation

It is known whether the AHUs are run at minimum OA; they could all very well be running at 100 percent OA, due to the lack of controls and the lack of maintenance. The design air flow of all AHUs together is approximately 103,000 cfm. On average, then the minimum OA ratio is 25 percent.

7.9.6 Investment

Required investments include: $5,000/AHU or a total of $85,000.

7.9.7 Payback

Simple payback will occur in less than 2 yrs.

8 Dining Facilities ECMs

8.1 DIN #1: Modify kitchen hoods with end skirts, Bldg 745

8.1.1 Existing conditions

The hoods used in the kitchen of the Cadet Mess Hall are standard canopy type hoods with no extensions down or end skirts, placed against a wall (Figure 33). The formula for the exhaust rate of a canopy hood against a wall is:

$$Q = 1.4*P*V*D$$

where:

P = 2 x hood width + hood length, ft
V = Hood velocity through hood opening, ft/min
D = Distance of hood above cooking surfaces, ft.

The velocity should be approximately 140 ft/min for the type of use in this kitchen. There are four hood exhaust system removing 12,600 cfm each and one that exhausts 14,400 cfm for a total exhaust of 64,800 cfm of air. These hoods operate approximately 15 hrs/day, 7 days/wk when the Cadets are present (estimated to equal 45 wks/yr).

The kitchen hood ventilation system is a large energy user. First, there is an electrical use to operate the exhaust fan motors. There is also a supply air system that must operate to deliver make-up air for the hood exhaust.

Figure 33. Typical kitchen hood with no extensions down or end skirts.

There is an electrical use to power these fans as well as operate the chillers that cool this air in the summer. In the winter, heat is required to temper the air to avoid cold spots in the kitchen.

8.1.2 Solution

The exhaust air from the kitchen hoods can be made to perform more effectively by adding skirts or wings on the left and right sides of the hood. These skirts would in essence extend the hood sides lower to better encapsulate the kitchen cooking devices that have been placed under the hood. This would allow for better capture of the cooking fumes by the hood and the exhaust air flow could be slightly reduced due to this performance improvement.

Once the skirts are added, the hood exhaust system air flow would need to be readjusted by testing the hood's performance. Issues such as room air movement can negatively affect hood performance so the new air flow rates would need to take those site conditions into account when making reductions in hood exhaust air flow.

If the hood skirts are not added, the kitchen hoods will continue to exhaust a higher air flow than needed, which results in an excessive energy use.

8.1.3 Energy savings

It is estimated that adding skirts to the kitchen hoods would allow a 10 percent reduction in exhaust air flow while achieving the same current hood capture performance. The estimated total exhaust air fan horsepower required is 60 horsepower (HP) and the supply air system requires 40 HP. Volumetric airflow rate and fan power have a cubed relationship

8.1.4 Fan power

HPo/HPn = (cfmo/cfmn)^3; or

HPn = HPo(cfmn/cfmo)^3

HPn = 100(.9)^3 = 73Hp

Power Savings = 100Hp – 73Hp = 27Hp

Assuming 105 hrs/wk for 45 wks:

Electric Energy Use Savings = 27Hp x 0.746kW/Hp x 105 hrs/wk X 45 wk/yr = 95,170 kWh/yr

The reduced air flow also provides reduced air tempering energy use. The 64,800 cfm requires approximately 216 tons of cooling using 300 cfm per ton. Since the exhaust/supply air system is a heat recovery type the cooling requirements will be reduced by 50 percent:

Extra cooling = 1.08 X 64,800 cfm X (92 – 72) °F X 10% X 50% X 1200 EFLH/yr = 84 million Btuh/yr

Cooling Energy Used = 84 million Btuh/12000 Btuh/ton hr X 1 kWh/ton hr = 7000 kWh/yr

Electrical cost savings= 102,170 kWh/yr X $0.125/kWh= $12,800/yr

Heating savings = 1.08 X 64,800 cfm X 10% X 4909 degree days X 24 hr/day/0.74 heating system efficiency = 1,114 million Btu/yr

Heating cost savings =1,114 million Btu/yr X $12.39/ million Btu = $13,800/yr

The total estimated cost savings is $26,600/yr.

8.1.5 Investment

The estimated cost to provide 4-ft by 4-ft long skirts to each side of the five hoods is $9,600. To rebalance the exhaust and supply air systems associated with these hoods is estimated to cost $10,000. The total investment cost is $19,600.

8.1.6 Payback

The resulting payback period is 0.7 yrs.

8.2 DIN #2: Repair freezer door seals, Building 745

8.2.1 Existing conditions

The Cadet Mess Hall at West Point has 24 refrigerators and freezers used to store food items. At least 50 percent have entry doors that are in need of repair (Figure 34). Many have gaskets that no longer seal, doors that are need adjustment to eliminate cracks or doors so badly damaged that they are bent with the inner steel panel missing exposing the internal insulation.

Figure 34. Damaged door to refrigerated room, i.e., no inside metal covering exposed insulation (note opening in plastic strips).

The poor condition of these doors allows cold air to leak from the walk-in coolers and to be replaced with warm room air. This causes the refrigeration equipment to run excessively, and wastes electrical energy.

8.2.2 Solution

Institute a repair program to get the walk-in cooler doors back into good working condition. Fix the damaged doors, adjust the hinges so they close properly, and replace gaskets that do not provide a good seal. Replace the automatic door closer if required.

If these doors are not repaired, electrical energy waste from the escaping cold air will continue.

8.2.3 Energy savings

An estimated 50 percent of the refrigerators and freezers have significant leaks, resulting in more than a 10 percent extra cooling energy use. The resulting electrical saving would be 41,800 kWh/yr for an annual savings of $5,225:

Electrical Waste = 160 HP X 80% capacity adjustment X 50% needing repair X 10% waste X 0.746 kWh/HP X 8760 hrs/yr = 41,800 kWh/yr

Electrical cost savings= 41,800 kWh/yr X $0.125/kWh= $5,225/yr

8.2.4 Investment

A through assessment should be made of the repairs necessary to determine the true amount. Assuming 12 of the doors needed seals for a repair cost of $2,000 and six required a major door repair at $3,000 each the total cost would be approximately $20,000.

8.2.5 Payback

The resulting payback period is 3.8 yrs.

8.3 DIN #3: Heat recovery from refrigeration machines, Building 745

8.3.1 Existing conditions

There are 24 refrigerators and freezers that support the cooking operations at the West Point Cadet Mess Hall. A review of the refrigerant equipment that is used to cool these units' shows 160 horsepower is needed to power the compressors. Two rooms were visited that contained these compressors, all of which are water cooled, using a cooling tower located on the roof (Figure 35). The leaving condenser water going to the cooling tower was measured at approximately 90 °F.

The Mess Hall uses large quantities of hot water for dish washing, cleaning pots and pans, and the preparation of food for cooking. Steam from the central energy plant is required to generate this hot water.

Figure 35. Rack of refrigerated room compressors.

8.3.2 Solution

Place a heat recovery heat exchanger in the condenser water piping after the condenser and before the cooling tower. This heat exchanger will extract some of the condenser heat from this water and add it to incoming cold water before it enters the hot water heater.

If this heat is not recovered, the cost for heating domestic hot water will continue to be higher than it needs to be.

8.3.3 Energy savings

The flow for each group of condensers is estimated to be 100 gpm and a reduction of 7 °F can be accomplished with the heat exchanger. This results in an energy saving of 3,100 million Btu/yr for a cost saving of $38,400:

Q = 100 gpm X 7 °F reduction X 8.3 Lb/gal X 60 min/hr X 18 hr/day X 365 day/yr/ 0.74 heating system efficiency = 3,100 million Btu/yr

Energy cost savings = 3,100 million Btu/yr x $12.39/ million Btu = $38,400/yr

8.3.4 Investment

Two heat exchangers are proposed with 800 ft of 2½-in. piping to connect the heat exchangers with the cold water piping before the hot water heaters. At the hot water heater a holding tank will be installed with level controls. Heated water from the refrigeration machines will fill the tank with warm water. When the hot water heater demands water, it will be taken from the new holding tank until it is empty, then untempered cold water will be used. The estimated cost for this system is $85K for the heat exchangers, piping, and holding tank.

8.3.5 Payback

The resulting payback period is 2.2 yrs.

9 Lighting ECMs

9.1 LI #1: Use occupancy sensors to shut off lights, Buildings 663, 714, 727 and various barracks

9.1.1 Existing conditions

Several large academic, administrative and barracks buildings are used throughout the day at West Point. This use has high and low periods of occupancy. Visits to these buildings found overhead lights on with a minimum of personnel in the buildings. The result is many of the lights could be turned off to save electrical energy.

An example is the shower/restrooms in the barracks. During the mid-morning and early afternoon, these spaces typically had all their lights operating with no one present. A similar situation was found in recreational buildings visited (663, 714, and 727). Rest rooms, locker, and meeting rooms were vacant with their lights on (e.g., Figure 36). It is expected that in a number of spaces in the academic buildings the same is true; lights could be turned off to save otherwise wasted electrical energy.

Figure 36. Empty space with light on.

9.1.2 Solution

In these spaces where use varies depending on the time and current activity, the lighting system can be best controlled by occupancy sensors. These occupancy sensors can be installed that automatically switch lights on when human movement is sensed. The lighting level will be maintained until a set period of time has elapsed with no human movement observed. A period of 20 to 30 minutes would be adequate to ensure the space is truly unoccupied.

Such lighting controls should be placed in all buildings at West Point that have varied use patterns. These spaces should also have fluorescent lighting since the time for the bulb to light is almost instantaneous. Lighting systems using sodium vapor, mercury vapor or metal halide lights take several minutes for measurable light to be produced after energizing the bulb and thus are not conducive to occupancy sensor control. If the lighting in these spaces is not better controlled, this energy waste will continue.

9.1.3 Savings

The major area of savings would be the installation of occupancy sensors in all restroom/shower areas in the barracks to reduce both electrical demand and energy. These sensors would turn the lights off during the low use periods of the day and in the early morning hours of the night. In the recreational buildings lights in low use spaces such as locker room lights would also have control. Savings would occur during the day when athletic events are not planned. Table 15 provides a summary of the savings potential based on the spaces visited. The total estimated energy cost savings is $40,270/yr.

Table 15. Lighting savings potential based on the spaces visited.

Building	Watts	Hrs off/ wk	KWh Saved	Cost Savings	No. Rooms	Sensor Cost	Payback Period
601	132000	6	35,640	$4,455	55	$16,500	3.7
663	640	25	720	$90	2	$600	6.7
714	1280	25	1,440	$180	3	$900	5.0
727	1088	25	1,224	$153	1	$300	2.0
738	3200	70	10,080	$1,260	10	$3,000	2.4
740	3200	70	10,080	$1,260	10	$3,000	2.4
745 D E	43776	25	49,248	$6,156	24	$7,200	1.2

Building	Watts	Hrs off/ wk	KWh Saved	Cost Savings	No. Rooms	Sensor Cost	Payback Period
745 C	32832	70	103,421	$12,928	18	$5,400	0.4
756	43776	70	137,894	$17,237	24	$7,200	0.4
753	27000	5	6,075	$759	6	$2,400	3.2
751	2560	70	8,064	$1,008	8	$2,400	2.4
Total			*363,886*	*$45,486*		*$48,900*	*1.1*

Example Calculation – Building 756, four shower/restrooms per floor X 6 floors = 24 spaces

Electrical savings = 19 fixtures X 0.096 kW X 24 spaces X 70 hr/wk X 45 wk/yr = 137,894 kWh/yr

Electrical cost savings = 137,894 kWh/yr X $0.125/Kwh = $17,237/yr

9.1.4 Investment

To install infrared wall mounted occupancy sensors where the lighting switches are located is approximately $300 each. Table 15 lists the total cost for the listed buildings. The total investment for this ECM is $48,900.

9.1.5 Payback

The payback for lighting controls in the subject buildings is 1.1 yrs. It is recommended that occupancy sensors be placed in all similar spaces that have fluorescent lighting.

9.2 LI #2: Shut off exterior lights during daytime

9.2.1 Existing conditions and problems

Exterior lights are ON outside some buildings at West Point during periods when there is no need for these lights. These lights are either intended to be switched on and off manually or by an automatic daylight sensor. Neither system always works. External lights left on during the daytime were observed at: Old PX (Bldg 683), Bldg 622 (bowling alley), Bldg 752 (roof), New PX Bldg 1204.

9.2.2 Solution

Check the function of existing daylight sensors. Replace sensors that do not work anymore. Install sensors where manual on/off is expected to be

done, to avoid unnecessary use of lights during daytime. As an extra security, to prevent long operating hours if daylight sensors fail: Install a timer that only makes power supply available between 5 p.m. and 7 a.m.

9.2.3 Savings

Example data from PX, Bldg 1204 was used, where the following was observed: At the garden center, a total of 18 fixtures with 285W lamps were ON (Figure 37). At the entrance to PX there were 12, 100W fixtures and eight 250W fixtures ON (Figure 38).

Figure 37. Garden center lights on.

Figure 38. PX entrance.

Annual energy savings can be calculated as follows:

Current hrs of operation = 8,760/yr

Proposed hrs of operation = 4,160/yr (nights only)

Energy savings = (18 * 285 W + 12 * 100 W + 8 * 250 W) * (8760 – 4160 hrs) = 38,300 kWh/yr. With 12.5 cents/kWh the value of the savings is $4,800/yr

9.2.4 Investment

Required investments include new daylight sensors (two PCs), to be installed, checked, and properly set, for $1,000.

9.2.5 Payback

Simple payback will occur within 3 months.

9.3 LI #3 Shut off interior lights during daytime in areas that are bright from daylight

9.3.1 Existing conditions and problems

There are spaces within buildings that are perfectly and beautifully lit up by daylight from outside, through skylights and/or windows. Despite that, the lights inside the building are **ON**. The use of artificial lights inside during these periods of the day does not make it any brighter inside than the daylight does. Therefore this is only a waste of energy.

9.3.2 Solution

Install light sensors that switch sets of interior, artificial lights **OFF** when the light levels are enough, for example above 300 lux (28 foot-candles). Also, install timers that do not allow these lights to be on at night.

9.3.3 Savings

To illustrate the savings with an example from PX, Bldg 1204, at the atrium, directly inside after entering through the main entrance, there are 15 100W fixtures and 14 fixtures with CFLs. Assume these fixtures are 40W each (Figure 39). During normal days these lights will not need to be ON, other than at periods when the daylight is reduced due to clouds, rain etc. On normal days, it will probably be possible to reduce the operating hours for these lights by 8 hrs/day, 7 days/wk:

Energy savings: (15 * 100 W + 14 * 40 W) * 8 hrs/day * 7 days * 52 wks = 6,000 kWh/yr.

Value of savings: 6,000 kWh * 12.5 cents/kWh = $750/yr.

9.3.4 Investment

Light sensor plus timer, installed, functionality checked: $1,000.

9.3.5 Payback

Simple payback will occur within 16 months.

9.4 LI #4: Replace incandescent lights with Compact Fluorescent Lamp (CFL) (Buildings 685, 622, 714)

9.4.1 Existing conditions and problems

Some locations still use of incandescent lights, for example in the main rehearsal room of the Band building (685) and in the Bowling Alley (622). Figure 40 shows the Band building incandescent lights. These lights are inefficient, and give very little light compared to the energy they use. One should also remember that most energy used in these light fixtures is converted to heat. Therefore, in the summer there is an increase in the use of cooling to reduce the space temperature.

Figure 39. PX atrium.

Figure 40. Incandescent lights.

9.4.2 Solution

Replace incandescent lights with CFLs.

9.4.3 Savings

In Bldg 685, replace 48 pieces of 120W incandescent lights with 20W CFLs.

In the Bowling Alley, replace 86 pieces of 100W incandescent lights with 20W dimmable CFL.

Assuming operating hours of 8 hrs/day, 7 days/wk (i.e., these lights are not left ON at night):

> Savings: (48 * (120 – 20 W) + 86 *(100 – 20 W)) * 8 hrs * 7 days * 52 wks = 34,000 kWh/yr worth $4,250/yr, assuming lights are not left on at night.

9.4.4 Investment

The required investment would include buying lamps, replacing existing lamps (same fixtures can be used), for:

> $15/lamp, totally (48 + 86) * 15 = $2,000.

9.4.5 Payback

Simple payback will occur within 6 months.

9.4.6 Comments

There are also incandescent lights at the entrance of Holleder Center. These should also be replaced. The numbers of lights and their wattage were not available to calculate the savings, but replacing those lights will certainly yield significant savings.

9.5 LI #5: Replace incandescent lights with compact fluorescent lights

9.5.1 Existing conditions and problems

Incandescent lights are extremely inefficient, producing very few lumens per Watt consumed. In addition, they get very hot and produce excess heat in the building, and they burn out quickly and need to be replaced often. While some of these have been replaced at West Point, there are still a number of them in various buildings on site. Some are used for exterior lighting, while others are used in administration, lodging, and service/morale, welfare, and recreation (MWR) facilities for interior lighting.

9.5.2 Current technology

Existing lighting fixtures use incandescent electric lights with energy use ranging from 60W to 200W.

9.5.3 Recommended solution

Replace all remaining incandescent lights with CFL with energy use ranging from 13W to 55W. CFLs use 65–80 percent less energy than incandescents with the same light output. They also last 7–10 times longer, reducing the need for maintenance hours and replacement bulbs. They are designed similarly to incandescents, allowing an easy switch of bulbs, rather than a complicated retrofit.

Energy Savings

Replacing all of these lights would result in a savings of 9,264 MMBtu/yr, according to FEDS calculations. This is a cost savings of $579,133/yr.

9.5.4 Additional benefits

There is also a significant amount of maintenance savings with this ECM, since CFLs last so much longer than incandescents. It would save $273,776/yr in maintenance costs.

9.5.5 Investment

Replacing these lights would cost $433,588.

9.5.6 Payback

Simple payback will occur in 0.5 yrs.

Table 16. Summary of LI #5: Replace incandescent lights with compact fluorescent lights.

ECM #	ECM Description	Electrical Savings			Thermal		Plant Energy Savings		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr	MBtu/yr	$/yr				
LI_5A	Replace incandescent lights with CFL	11	1	$432	0	$–	0	$–	$141	$573	$186	0.3
LI_5B	Replace incandescent lights with CFL	14	0	$474	0	$–	0	$–	$175	$649	$340	0.5
LI_5C	Replace incandescent lights with CFL	461	19	$16,339	–268	$(3,326)	0	$–	$5,335	$18,348	$10,358	0.6
LI_5D	Replace incandescent lights with CFL	27	4	$974	0	$–	0	$–	$279	$1,253	$2,087	1.7
LI_5E	Replace incandescent lights with CFL	168	7	$5,980	–74	$(920)	0	$–	$1,881	$6,941	$2,597	0.4
LI_5F	Replace incandescent lights with CFL	131	17	$4,675	0	$–	0	$–	$1,838	$6,513	$8,904	1.4
LI_5G	Replace incandescent lights with CFL	1796	100	$67,184	–995	$(15,197)	0	$–	$22,711	$74,698	$28,602	0.4
LI_5H	Replace incandescent lights with CFL	384	50	$14,787	0	$–	0	$–	$4,938	$19,725	$14,610	0.7
LI_5I	Replace incandescent lights with CFL	490	32	$18,919	–86	$(1,069)	0	$–	$5,122	$22,972	$7,267	0.3
LI_5J	Replace incandescent lights with CFL	1341	114	$53,864	–643	$(7,971)	0	$–	$16,713	$62,606	$36,565	0.6
LI_5K	Replace incandescent lights with CFL	1	0	$57	0	$–	0	$–	$22	$79	$31	0.4
LI_5L	Replace incandescent lights with CFL	2	0	$81	0	$–	0	$–	$35	$116	$186	1.6
LI_5M	Replace incandescent lights with CFL	698	35	$23,899	–428	$(5,306)	0	$–	$9,307	$27,900	$15,259	0.5
LI_5N	Replace incandescent lights with CFL	2264	121	$80,834	–1707	$(21,669)	0	$–	$30,713	$89,878	$50,355	0.6
LI_5O	Replace incandescent lights with CFL	794	41	$27,318	–572	$(8,858)	0	$–	$10,743	$29,203	$17,767	0.6
LI_5P	Replace incandescent lights with CFL	1810	71	$62,315	–1000	$(12,388)	0	$–	$24,527	$74,454	$40,562	0.5
LI_5Q	Replace incandescent lights with CFL	713	36	$24,551	–447	$(5,537)	0	$–	$9,634	$28,648	$15,932	0.6
LI_5R	Replace incandescent lights with CFL	597	33	$20,567	–360	$(4,458)	0	$–	$8,175	$24,284	$13,520	0.6
LI_5S	Replace incandescent lights with CFL	621	32	$21,392	–424	$(6,423)	0	$–	$8,342	$23,311	$13,677	0.6
LI_5T	Replace incandescent lights with CFL	1794	91	$61,778	–1132	$(14,031)	0	$–	$24,107	$71,854	$39,867	0.6
LI_5U	Replace incandescent lights with CFL	240	9	$8,211	–145	$(1,792)	0	$–	$3,208	$9,627	$5,260	0.5
LI_5V	Replace incandescent lights with CFL	1262	67	$43,550	–897	$(12,595)	0	$–	$17,155	$48,110	$28,371	0.6

ECM #	ECM Description	Electrical Savings			Thermal		Plant Energy Savings		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr	MBtu/yr	$/yr				
LI_5W	Replace incandescent lights with CFL	4992	334	$179,577	–2261	$(41,420)	0	$–	$66,393	$204,550	$75,935	0.4
LI_5X	Replace incandescent lights with CFL	16	1	$575	0	$–	0	$–	$184	$759	$2,640	3.5
LI_5Y	Replace incandescent lights with CFL	17	1	$574	0	$–	0	$–	$105	$679	$396	0.6
LI_5Z	Replace incandescent lights with CFL	44	3	$1,738	0	$–	0	$–	$791	$2,529	$969	0.4
LI_5AA	Replace incandescent lights with CFL	37	4	$1,469	–24	$(293)	0	$–	$1,012	$2,188	$1,159	0.5
LI_5AB	Replace incandescent lights with CFL	9	1	$354	–7	$(83)	0	$–	$190	$461	$186	0.4
Totals		*20733*	*1224*	*$742,468*	*–11470*	*$(163,336)*	*0*	*$–*	*$273,776*	*$852,908*	*$433,588*	*20.2*

9.6 LI#6: Replace exit signs with electroluminescent exit signs or retrofit kits

9.6.1 Existing conditions and problems

Most exit signs at West Point have been replaced with 2-Watt light emitting diode (LED) exit signs. There are a few that are still incandescent, using 40W. Exit signs are never turned off, so the smallest wattage sign will almost always be cost-effective.

9.6.2 Current technology

Current technologies are incandescent, fluorescent, and/or LED.

9.6.3 Recommended solution

Electroluminescent exit signs use only 0.2 Watts. Therefore, it is cost-effective to replace all exit signs with these, using 10–200 times less energy than the current sign. Because of these cost more than LED style exit signs, it may make more sense to continue using LED exit signs where they are prone to damage or vandalism.

9.6.4 Energy savings

FEDS calculates that replacing all the exit signs will save 2,978 MMBtu/yr, and $167,515/yr.

9.6.5 Additional benefits

Electroluminescent exit signs have a much longer lifetime than incandescents and even LEDs. Therefore maintenance savings is significant – $144,814/yr.

9.6.6 Investment

Installation of the new exit signs would cost $430,802.

9.6.7 Payback

Simple payback will occur in 1.4 yrs.

Table 17. Summary of LI#6: Replace exit signs with electroluminescent exit signs or retrofit kits.

ECM #	ECM Description	Electrical Savings			Thermal		Plant Energy Savings		Maintenance	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint	Investment	Simple Payback
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr	MBtu/yr	$/yr	$/yr	$/yr	$	yrs
LI_6A	Replace existing exit signs with electroluminescent exit signs	725	24	$25,320	0	$–	0	$–	$14,772	$40,092	$40,166	1.0
LI_6B	Replace existing exit signs with electroluminescent exit signs	120	1	$4,161	0	$–	0	$–	$2,317	$6,478	$6,301	1.0
LI_6C	Replace existing exit signs with electroluminescent exit signs	57	2	$1,986	–33	$(405)	0	$–	$1,159	$2,740	$3,150	1.1
LI_6D	Replace existing exit signs with electroluminescent exit signs	57	2	$1,986	–33	$(405)	0	$–	$1,159	$2,740	$3,150	1.1
LI_6E	Replace existing exit signs with electroluminescent exit signs	1233	56	$43,999	–939	$(11,917)	0	$–	$22,882	$54,964	$62,218	1.1
LI_6F	Replace existing exit signs with electroluminescent exit signs	222	9	$7,875	–161	$(2,484)	0	$–	$4,055	$9,446	$11,026	1.2
LI_6G	Replace existing exit signs with electroluminescent exit signs	423	19	$15,112	–255	$(3,156)	0	$–	$7,820	$19,776	$21,264	1.1
LI_6H	Replace existing exit signs with electroluminescent exit signs	378	17	$13,503	–264	$(3,989)	0	$–	$6,952	$16,466	$18,902	1.1
LI_6I	Replace existing exit signs with electroluminescent exit signs	601	27	$21,428	–426	$(5,980)	0	$–	$11,007	$26,455	$29,928	1.1
LI_6J	Replace existing exit signs with electroluminescent exit signs	394	13	$13,736	–44	$(539)	0	$–	$8,014	$21,211	$21,790	1.0
LI_6K	Replace existing exit signs with electroluminescent exit signs	106	4	$3,790	–30	$(378)	0	$–	$2,124	$5,536	$5,776	1.0
LI_6L	Replace existing exit signs with electroluminescent exit signs	16	1	$574	–7	$(82)	0	$–	$290	$782	$788	1.0
LI_6M	Replace existing exit signs with electroluminescent exit signs	44	2	$1,557	–23	$(288)	0	$–	$772	$2,041	$2,100	1.0
LI_6N	Replace existing exit signs with electroluminescent exit signs	14	0	$490	–3	$(39)	0	$–	$290	$741	$788	1.1
LI_6O	Replace existing exit signs with electroluminescent exit signs	189	6	$6,664	–77	$(1,405)	0	$–	$3,476	$8,735	$9,451	1.1
LI_6P	Replace existing exit signs with electroluminescent exit signs	228	8	$7,944	–166	$(2,057)	0	$–	$4,634	$10,521	$12,601	1.2
LI_6Q	Replace existing exit signs with electroluminescent exit signs	199	7	$6,950	–135	$(1,672)	0	$–	$4,055	$9,333	$11,026	1.2
LI_6R	Replace existing exit signs with electroluminescent exit signs	49	2	$1,737	–25	$(307)	0	$–	$2,885	$4,315	$3,150	0.7
LI_6S	Replace existing exit signs with electroluminescent exit signs	227	8	$7,920	0	$–	0	$–	$15,387	$23,307	$16,802	0.7
LI_6T	Replace existing exit signs with electroluminescent exit signs	109	5	$3,862	–55	$(782)	0	$–	$4,813	$7,893	$15,751	2.0
LI_6U	Replace existing exit signs with electroluminescent exit signs	275	12	$9,785	–93	$(1,234)	0	$–	$11,550	$20,101	$37,804	1.9
LI_6V	Replace existing exit signs with electroluminescent exit signs	31	1	$1,090	–12	$(146)	0	$–	$1,444	$2,388	$4,725	2.0
LI_6W	Replace existing exit signs with electroluminescent exit signs	11	0	$382	0	$–	0	$–	$481	$863	$1,575	1.8
LI_6X	Replace existing exit signs with electroluminescent exit signs	27	1	$950	–19	$(233)	0	$–	$1,444	$2,161	$4,725	2.2

ECM #	ECM Description	Electrical Savings			Thermal		Plant Energy Savings		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr	MBtu/yr	$/yr				
LI_6Y	Replace existing exit signs with electroluminescent exit signs	1	0	$46	–1	$(9)	0	$–	$202	$239	$1,575	6.6
LI_6Z	Replace existing exit signs with electroluminescent exit signs	2	0	$69	–1	$(14)	0	$–	$304	$359	$2,363	6.6
LI_6AA	Replace existing exit signs with electroluminescent exit signs	11	1	$401	–5	$(64)	0	$–	$1,822	$2,159	$14,176	6.6
LI_6AB	Replace existing exit signs with electroluminescent exit signs	4	0	$126	–2	$(20)	0	$–	$506	$612	$3,938	6.4
LI_6AC	Replace existing exit signs with electroluminescent exit signs	2	0	$82	–1	$(9)	0	$–	$405	$478	$3,150	6.6
LI_6AD	Replace existing exit signs with electroluminescent exit signs	11	0	$397	–6	$(77)	0	$–	$1,619	$1,939	$12,601	6.5
LI_6AE	Replace existing exit signs with electroluminescent exit signs	4	0	$124	–3	$(33)	0	$–	$607	$698	$4,725	6.8
LI_6AF	Replace existing exit signs with electroluminescent exit signs	9	0	$310	–2	$(24)	0	$–	$1,518	$1,804	$11,814	6.5
LI_6AG	Replace existing exit signs with electroluminescent exit signs	0	0	$7	0	$(1)	0	$–	$34	$40	$263	6.6
LI_6AH	Replace existing exit signs with electroluminescent exit signs	2	0	$55	–1	$(14)	0	$–	$270	$311	$2,100	6.8
LI_6AI	Replace existing exit signs with electroluminescent exit signs	2	0	$83	0	$–	0	$–	$405	$488	$3,150	6.5
LI_6AJ	Replace existing exit signs with electroluminescent exit signs	3	0	$122	–1	$(7)	0	$–	$506	$621	$3,938	6.3
LI_6AK	Replace existing exit signs with electroluminescent exit signs	20	1	$717	–5	$(58)	0	$–	$2,834	$3,493	$22,052	6.3
0	Do not Use	0	0	$–	0	$–	0	$–	$–	$–	$–	–
Totals		*5806*	*229*	*$205,340*	*–2828*	*$(37,828)*	*0*	*$–*	*$144,814*	*$312,326*	*$430,802*	*1.3*

9.7 LI #7: Replace T8 lamps with Super T8 lamps

9.7.1 Existing conditions and problems

Most buildings on site use T8 fluorescent fixtures to light offices, hallways, labs, and other work areas. While not terribly inefficient, there are better options for general lighting.

9.7.2 Current technology

Current technologies are 2-lamp, 3-lamp, and 4-lamp T8 fixtures.

9.7.3 Recommended solution

Super T8 lights are similar to T8s, but are more efficient. They are the same size, and so the replacement is easy. The following replacements are recommended:

- FL 49 (4-Lamp 32W T8s) replaced with FL 280 (3% reduction in Lumens)
- FL 50 (3-Lamp 32W T8s) replaced with FL 304 (0% reduction in Lumens)
- FL 51 (2-Lamp 32W T8s) replaced with FL 303 (0% reduction in Lumens).

9.7.4 Energy savings

Replacing T8s with Super T8s would save 2,223 MMBtu/yr, according to FEDS calculations. The cost savings would be $105,371/yr.

9.7.5 Additional benefits

There would also be a maintenance savings of $24,808/yr.

9.7.6 Investment

This ECM would cost $1,155,946 to implement.

9.7.7 Payback

Simple payback will occur in 8.9 yrs.

Table 18. Summary of LI #7: Replace T8 lamps with Super T8 lamps.

		Electrical Savings			Thermal		Plant Energy Savings					
ECM #	ECM Description	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr	MBtu/yr	$/yr	Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
LI_7A	Replace T8 lighting with Super T8 lighting	171	14	$6,877	–37	$(461)	0	$–	$842	$7,258	$39,565	5.5
LI_7B	Replace T8 lighting with Super T8 lighting	458	38	$18,277	–146	$(1,804)	0	$–	$3,428	$19,901	$78,108	3.9
LI_7C	Replace T8 lighting with Super T8 lighting	25	2	$896	–4	$(46)	0	$–	$134	$984	$6,058	6.2
LI_7D	Replace T8 lighting with Super T8 lighting	104	5	$3,809	0	$–	0	$–	$1,847	$5,656	$72,579	12.8
LI_7E	Replace T8 lighting with Super T8 lighting	134	11	$5,082	–42	$(516)	0	$–	$2,163	$6,729	$80,061	11.9
LI_7F	Replace T8 lighting with Super T8 lighting	199	6	$6,946	0	$–	0	$–	$15	$6,961	$49,017	7.0
LI_7G	Replace T8 lighting with Super T8 lighting	208	9	$7,588	–56	$(694)	0	$–	$1,259	$8,153	$69,964	8.6
LI_7H	Replace T8 lighting with Super T8 lighting	41	3	$1,503	–6	$(76)	0	$–	$76	$1,503	$21,263	14.1
LI_7I	Replace T8 lighting with Super T8 lighting	33	2	$1,257	–6	$(78)	0	$–	$52	$1,231	$15,520	12.6
LI_7J	Replace T8 lighting with Super T8 lighting	510	26	$18,430	0	$–	0	$–	$7,682	$26,112	$254,576	9.7
LI_7K	Replace T8 lighting with Super T8 lighting	286	23	$11,368	–93	$(1,148)	0	$–	$1,053	$11,273	$109,659	9.7
LI_7L	Replace T8 lighting with Super T8 lighting	588	43	$22,922	–247	$(3,060)	0	$–	$2,470	$22,332	$202,215	9.1
LI_7M	Replace T8 lighting with Super T8 lighting	243	22	$9,532	–148	$(1,833)	0	$–	$3,748	$11,447	$151,553	13.2
LI_7N	Replace T8 lighting with Super T8 lighting	19	1	$734	–11	$(134)	0	$–	$39	$639	$5,808	9.1
0	Do not Use	0	0	$–	0	$–	0	$–	$–	$–	$–	–
Totals		*3019*	*205*	*$115,221*	*–796*	*$(9,850)*	*0*	*$–*	*$24,808*	*$130,179*	*$1,155,946*	*8.8*

9.8 LI #8: Replace metal halide and incandescent lights with misc higher efficiency lighting

9.8.1 Existing conditions and problems

Older incandescent and metal halide lights are inefficient. More efficient lighting products exist.

9.8.2 Current technology

Current technologies are incandescent and older metal halide lights.

9.8.3 Recommended solution

Replace inefficient metal halide 150W lights with high efficiency metal halide 150W lighting. Replace 250W metal halide lights with 40W 6-bulb biaxial lights with reflectors. Although the biaxial lights have a relatively low lumen per Watt and are expensive, life cycle costs are better than the existing fixtures. Another possibility is Super T8s, however this was not analyzed.

9.8.4 Energy savings

Retrofitting these exterior lights was calculated by FEDS to save 498 MMBtu/yr. The cost savings would be $23,094/yr.

9.8.5 Additional benefits

There would also be a maintenance savings of $9,144/yr.

9.8.6 Investment

This ECM would cost $263,543 to implement.

9.8.7 Payback

Simple payback will occur in 8.2 yrs.

Table 19. Summary of LI #8: Replace metal halide and incandescent lights with misc higher efficiency lighting.

		Electrical Savings			Thermal		Plant Energy Savings			Total Savings: Electrical Use, Elec Demand, Thermal, and Maint		Simple
ECM #	ECM Description	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr	MBtu/yr	$/yr	Maintenance $/yr	$/yr	Investment $	Payback yrs
LI_8A	Replace MH with Biaxial Florescent lighting	374	31	$14,963	–100	$(1,236)	0	$–	$4,701	$18,428	$145,713	7.9
LI_8B	Replace MH with Biaxial Florescent lighting	173	12	$6,344	–32	$(391)	0	$–	$2,541	$8,494	$70,963	8.4
LI_8C	Replace MH with Biaxial Florescent lighting	95	6	$3,472	–17	$(215)	0	$–	$1,391	$4,648	$38,846	8.4
LI_8D	Replace MH with High Efficient Electronic ballast MH lighting	5	0	$157	0	$–	0	$–	$511	$668	$8,021	12.0
Totals		*647*	*49*	*$24,936*	*–149*	*$(1,842)*	*0*	*$–*	*$9,144*	*$32,238*	*$263,543*	*8.1*

9.9 LI #9: Replace T12 with Super T8 lighting

9.9.1 Existing conditions and problems

Although it is common to replace the older T12 lights with T8 lights, in certain applications, the more efficient Super T8s are a better replacement.

9.9.2 Current technology

Current technologies are 4-lamp T12 fixtures.

9.9.3 Recommended solution

Super T8 lights are similar to T8s, but are more efficient. Replace 40W 4-bulb T12s fixtures with 32W 3-bulb Super T8s fixtures with reflectors:

- FL1: FL 2X4 4F40T12 STD2 replaced with FL280: FL 2X4 3F32ST8 ELC3 REF (FIX REPL)
- FL1 FL 2X4 4F40T12 STD2 replaced with FL244: FL 2X4 4F32T8 ELC4
- FL3 FL 2X4 2F40T12 STD2 replaced with FL51: FL 2X4 2F32T8 ELC2
- FL29: FL 1X4 1F40T12 ELC1 replaced with FL53: FL 1X4 1F32T8 ELC1.

9.9.4 Energy savings

Retrofitting these exterior lights was calculated by FEDS to save 2,090 MMBtu/yr. The cost savings would be $133,056/yr.

9.9.5 Additional benefits

There would also be a maintenance savings of $64,728/yr.

9.9.6 Investment

This ECM would cost $994,250 to implement.

9.9.7 Payback

Simple payback will occur in 5.0 yrs.

9.10 LI #10: Replace existing metal halide lighting in high bay areas with T5 fluorescent lighting systems

9.10.1 Existing conditions and problems

High bay areas are somewhat difficult to light since the light source is so far away from where it is being used. High output lights are needed in these areas for an efficient, well-lit space. Some buildings at West Point use metal halide lamps, which work well and are common, but not the most efficient choice.

9.10.2 Current technology

Current technologies are metal halide lamps.

9.10.3 Recommended solution

Use T5 fluorescent lights in high bay areas. These have a high output and are some of the most efficient options on the market. Replace larger metal halides with 4-bulb, 4-ft fixtures with reflectors. Replace smaller metal halides with 3-bulb, 4-ft fixtures. Another option is the use of high performance T8 systems with are approximately 15 percent more efficient than the T5 solution and may cost less (but was not analyzed in this study.)

9.10.4 Energy savings

FEDS calculated that replacing these lights with T5s would save 95 MMBtu/yr. The cost savings would be $4,207/yr.

9.10.5 Additional benefits

There would also be a maintenance savings of $5,290/yr.

9.10.6 Investment

This ECM would cost $37,863 to implement.

9.10.7 Payback

Simple payback will occur in 4.0 yrs.

Table 20. Summary of LI #9: Replace T12 with Super T8 lighting.

ECM #	ECM Description	Electrical Savings			Thermal		Plant Energy Savings		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr	MBtu/yr	$/yr				
LI_9A	Replace T12 with Super T8 lighting	489	41	$19,532	–297	$(3,682)	0	$–	$4,616	$20,466	$114,564	5.6
LI_9B	Replace T12 with Super T8 lighting	1744	72	$61,718	–1180	$(14,620)	0	$–	$13,355	$60,453	$149,602	2.5
LI_9C	Replace T12 with Super T8 lighting	119	6	$4,157	–83	$(1,055)	0	$–	$1,583	$4,685	$27,430	5.9
LI_9D	Replace T12 with Super T8 lighting	42	2	$1,432	–28	$(432)	0	$–	$611	$1,611	$9,678	6.0
LI_9E	Replace T12 with Super T8 lighting	95	4	$3,259	–49	$(602)	0	$–	$1,395	$4,052	$22,096	5.5
LI_9F	Replace T12 with Super T8 lighting	37	2	$1,280	–22	$(269)	0	$–	$548	$1,559	$8,679	5.6
LI_9G	Replace T12 with Super T8 lighting	31	2	$1,077	–17	$(216)	0	$–	$465	$1,326	$7,365	5.6
LI_9H	Replace T12 with Super T8 lighting	17	1	$592	–11	$(166)	0	$–	$228	$654	$3,944	6.0
LI_9I	Replace T12 with Super T8 lighting	94	5	$3,244	–55	$(681)	0	$–	$1,371	$3,934	$21,717	5.5
LI_9J	Replace T12 with Super T8 lighting	13	0	$432	–7	$(87)	0	$–	$165	$510	$2,865	5.6
LI_9K	Replace T12 with Super T8 lighting	66	3	$2,283	–43	$(614)	0	$–	$976	$2,645	$15,455	5.8
LI_9L	Replace T12 with Super T8 lighting	1443	123	$58,276	–368	$(4,891)	0	$–	$21,417	$74,802	$372,718	5.0
LI_9M	Replace T12 with Super T8 lighting	55	2	$1,991	–23	$(377)	0	$–	$9,079	$10,693	$120,131	11.2
LI_9N	Replace T12 with Super T8 lighting	54	2	$1,956	–26	$(479)	0	$–	$8,919	$10,396	$118,006	11.4
Totals		*4299*	*265*	*$161,229*	*–2209*	*$(28,171)*	*0*	*$–*	*$64,728*	*$197,786*	*$994,250*	*5.0*

10 Electrical ECMs

10.1 EL #1: Use energy efficient electric motors; Buildings 750, 5102, 5440, 6901

10.1.1 Existing conditions

Electric motors are required to power a wide range of equipment and devices. The loads on the motors can vary or be relative constant. When selecting a motor, it is best to match the process load to the proper motor size. A partially loaded motor operates less efficiently than one fully loaded. Motor efficiency ranges from 75 percent for a standard 1 hp 3-phase induction motor operating at full load to 90 percent for a standard 50 hp motor.

In 1992 the Energy Policy Act was passed that required most motors manufactured after October 1997 to meet higher efficiency standards. The efficiency set for 1 and 50 horsepower motors are 82.5 and 93 percent respectively. Later premium efficient motors became available at extra cost whose efficiencies range from 85.5 to 94.13 percent for the same range of motors. Single phase motors are normally 5 to 10 percent lower in efficiency. Another benefit of the higher efficient motors is they run cooler and should provide a longer service life. (Figure 41 shows a typical pump motor.)

Electric motors have a limited life. When they become inoperable, they typically can be repaired by rewinding to become functional again. A downside to this repair is a loss in efficiency. It is often more economical to replace a burnt out motor with a new premium motor than to rewind it. The cost difference between operating the two motors will easily pay for the extra cost of the new one.

Table 21. Summary of LI #10: Replace existing metal halide lighting in high bay areas with T5 fluorescent lighting systems.

		Electrical Savings			Thermal		Plant Energy Savings					
ECM #	ECM Description	KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr	MBtu/yr	$/yr	Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
LI_10A	Replace metal halide high–bay lighting with T5 lighting	54	4	$2,133	0	$–	0	$–	$4,136	$6,269	$21,429	3.4
LI_10B	Replace metal halide high–bay lighting with T5 lighting	65	3	$2,371	–24	$(297)	0	$–	$1,154	$3,228	$16,434	5.1
Totals		*119*	*7*	*$4,504*	*–24*	*$(297)*	*0*	*$–*	*$5,290*	*$9,497*	*$37,863*	*3.9*

Figure 41. Typical pump motor.

10.1.2 Solution

West Point has a number of electric motors that were not the premium efficiency type. Standard and high efficient horsepower motors were found that powered pumps and fans at the following locations:

- Building 620 has a 15 HP pump motor @ 87.5% efficiency and a 20 HP pump motor @ 88.5% efficiency
- Building 624 has 7.5 HP pump motor @ 87.5% efficiency and a 20 HP pump motor @ 90% efficiency
- Building 727 has two 15 HP pump motors @ 91% efficiency and two 20 HP pump motors—one @ 88.5% efficiency and the other @ 91% efficiency
- Building 745 has two 3 HP pump motors—one @ 81.5% efficiency and the other @ 84% efficiency.

It is recommended to replace these motors with premium efficient motors when they fail and need replacement. The following tables show the annual savings and the cost of the premium motors compared to the use of standard efficiency motors. The analysis shown in the tables assume that the motors operate continuously and are fully loaded. The cost used in the simple payback calculation is half the premium cost, which approximates the cost of a new motor compared to rewinding a failed motor.

Table 22. Comparison of premium efficiency with standard motors.

Motor Size	Existing Efficiency (%)	Proposed Efficiency (%)	Energy Saved (kWh/yr)	Energy Cost Savings ($/yr)	Total Cost Premium ($)	Additional Cost of New Motor vs. Rewinding	Simple Payback (yrs)
25	89.00%	93.60%	7,515	$939	$975	$488	0.5
20	88.00%	93.60%	7319	$915	$850	$425	0.5
15	87.50%	93.00%	5391	$674	$671	$335	0.5
10	86.00%	91.70%	3,725	$466	$520	$260	0.6
7.5	85.50%	91.00%	2,696	$337	$424	$212	0.6
5	85.00%	89.50%	1,470	$184	$295	$144	0.8
3	82.00%	89.70%	1,470	$184	$230	$115	0.6
1	76.00%	85.50%	621	$78	$185	$93	1.2

Table 23. Comparison of premium efficiency with post 1997 motors.

Motor Size	Existing Efficiency (%)	Proposed Efficiency (%)	Energy Saved (kWh/yr)	Energy Cost Savings ($/yr)	Total Cost Premium ($)	Additional Cost of New Motor vs. Rewinding	Simple Payback (yrs)
25	91.70%	93.60%	3,104	$388	$975	$488	1.3
20	91.00%	93.60%	3,398	$425	$850	$425	1.0
15	91.00%	93.00%	1,960	$245	$671	$335	1.4
10	89.50%	91.70%	1,438	$180	$520	$260	1.4
7.5	88.50%	91.00%	1,225	$153	$424	$212	1.4
5	87.50%	89.50%	653	$82	$295	$144	1.8
3	86.50%	89.70%	588	$74	$230	$115	1.6
1	82.50%	85.50%	196	$25	$185	$93	3.8

If West Point does not conduct a high efficiency motor replacement program, they will continue to waste energy unnecessarily.

10.1.3 Savings

The estimated savings of operating a premium efficient motor instead a lesser efficient one is listed in Tables 22 and 23. The savings in Tables 22 and 23 are based on continuous operation. The estimated savings of the identified pump motors is 17,350 kWh/yr for a $2,170 annual cost savings. It is assumed the motors at West Point are operating half the time.

10.1.4 Investments

The cost of a new premium efficient motor is provided in Tables 22 and 23. It is assumed in the simple payback calculations that the cost of rewinding the old motor is half the cost of a new premium efficient motor. The estimated cost to replace these motors is $6,300 and the additional cost when a rewinding is required would be $3,150.

10.1.5 Payback

The simple payback of installing a new premium efficient motor is shown in Tables 22 and 23. The resulting payback period for the subject motors at the time of rewinding is 1.5 yrs.

10.2 EL #2: Switch off computers when not in use basewide

10.2.1 Existing conditions

The personal computers in the area are mainly on always as Information Technology (IT) support suggests to facilitate software updates and backup runs. Building occupants are advised to switch screens off for the night in offices and computer classrooms, but it is likely that many screens and even projectors are on always.

In Bartlett Hall (753) and in Thayer Hall (601), there are several computer classrooms. There are many offices in all of the buildings.

10.2.2 Solution

Activate power-save features or switch computers off when not in use. The power saving settings will allow turning the screen off or hibernating the hard disk.

Updates and backups can be programmed to take place when the computer is switched on or during the lunch-break, or the computers can be started on remote control so that IT can then run updates at night and then switch them off again.

10.2.3 Savings

Savings have been calculated assuming that a computer with 17-in. or 19-in. monitor is using 150W when the screen is on and that a PC in stand-by mode in night-time with flat screen turned off is using 50 W.

The electricity price is 125 $/MWh and the yearly saving $38/computer.The weekly power-on time for the computers will be reduced from 168 hrs to 50 hrs = 118 hrs. Savings are calculated as:

Savings = 118 hrs/wk x 52 wks/yr x 50W = 306,8 kWh/yr

If it is estimated that there are 20 computer classrooms in the area, with about 20 PCs in each (total of 400) and about 1500 computers in different offices and classrooms, the total yearly saving for 1900 PCs is $72,800.

Additional saving may be possible from reduced peak demand if the electricity tariff includes a peak demand cost.

10.2.4 Investment

This ECM requires no investment; most computers already have the possibility for power saving. New advice and instructions from IT support are needed.

10.2.5 Payback

Simple payback will occur immediately.

11 HVAC ECMs

11.1 HVAC #1: Glycol heat recovery change

11.1.1 Existing conditions

The AHUs for the laboratories in Bartlett Hall have water-glycol heat recovery system from extract air. There are two coils on the extract units and 3–4 coils on supply air units located in the mechanical room on top of the laboratories.

The information on the glycol content in the heat recovery loop was given by the DPW; the solution is always 50 percent glycol, 50 percent water.

11.1.2 Solution

It is not necessary to have such high glycol content, this ratio means that the freezing point is about –38 °C. The higher the glycol content, the poorer the heat recovery efficiency and the higher the pumping cost. With the 50/50 ratio, the heat recovery efficiency is estimated to be about 30–35 percent.

By changing the glycol solution into a different glycol content (30 percent glycol), the heat recovery efficiency could be improved up to a value of 45–50 percent.

The glycol network should be emptied and a new solution with the right mix pumped in. Diluting the existing solution by adding water may bring up freezing problems.

11.1.3 Savings

The two AHUs for Bartlett Hall laboratories have a total air flow of about 13 m^3/s = 27,540 cfm. The units are running all the time, 8,760 h/yr.

The heating season is estimated to be about 7 months (October-April) and the average outdoor temperature during the heating season is about 4.6 °C = 40 °F. The average supply air temperature is about 20 °C = 68 °F and the extract air temperature about 22 °C = 72 °F.

Based on these assumptions, the saving from improving the yearly heat recovery efficiency from 30 to 45 percent is about 200 MWh/yr = 6,825 therms/yr. The change in glycol content will also reduce pumping costs, but the saving in electricity consumption is fairly small and therefore has not been estimated.

The output energy cost is $53.40 MWh/yr.

Thus the yearly saving is about $10,700 /yr.

11.1.4 Investments

The glycol solution needs to be pumped out and handled as hazardous waste. The new solution should be a ready mix with uniform glycol content.

The estimated cost of the new water-glycol solution is about $5,000.

11.1.5 Payback

The direct payback is:

$5,000/$10,700/yr = 0.5 yrs.

11.2 HVAC #2: heat recovery from computer room air-conditioning

11.2.1 Existing conditions

The two air handling units for the offices in Spellman Hall (Bldg 2101) operate on 100 percent outdoor air. AC 11 and AC 12 supply air to the North and South side of the office building (floors 2–5). The units have heating and cooling coils, no heat recovery, and no recirculation air. The units are located on the roof of the office part.

In addition to these two supply air units, there is a larger unit H&V1 for the wood and metal shop on the first floor, where the unit is located. This unit uses partly recirculation air.

All the air handling units operate 24/7.

11.2.2 Solution

There are computer rooms in the low wing of the building. The rooms have air-conditioning units running all the time with condensers on the roof, blowing out the extra heat.

The units AC1 through AC6 (six total) are glycol cooled, with an electrical power input of about 13 kW each. This means that there is max 270 kW = 922 MBTU/h of condensing heat available.

AC8, AC9, and AC10 are DX-units with a condenser on the ground at the back of the building. The electrical power input of these units is about 10 kW each. There is max 105 kW = 360 MBTU/h condensing heat available. Assuming that the computer room AC-units are running with 60 percent capacity during the heating season, the condensing capacity available for supply air pre-heating is about between 200 to 220 kW = 680 to 750 MBTU/h.

About 100 kW = 340 MBTU/h is needed for heating the supply air of the air handling units from 0 °C to about 20°C. Another 100 kW = 340 MBTU/h is needed if the H&V1 unit is running on 50 percent outdoor air during the heating season. Basically, all the heating energy needed for the air handling units could be obtained from the condensers of the computer room air-conditioning units.

11.2.3 Savings

Based on the following assumptions:

- The heating season is estimated to be about 7 months (October-April) and the average outdoor temperature during the heating season is about 4.6 °C = 40 °F.
- The average supply air temperature is about 20 °C = 68 °F.
- The total air flow of the two rooftop supply air units is 4.1 m^3/s = 8,500 cfm.
- The air flow of the wood and metal shop recirculation unit is 8 m^3/s = 17,000 cfm and the estimated outdoor air flow is 50 percent.
- The estimated saving in heating energy is about 600 MWh/yr = 20,470 Therms/yr if condensing heat is used for the three supply air units.

The output energy cost is \$53.40 MWh/yr.

Thus, the yearly saving is about \$32,000.

11.2.4 Investment

To use the condensing heat from the computer room air-conditioning units, a pre-heating coil should be added to the supply air units. This heating coil should operate parallel to the existing condensers (to let the extra heat not consumed by the air handling units into the condensers) and in sequence with the heating coils (to use first the full capacity of the pre-heater before using boiler produced heat).

The same principle can be used for the DX systems and for the glycol condensing loop.

The cost estimate for the preheating coil for the three air handling units, pipeline to the roof, controls, changes in the existing condenser system, etc. is about \$50,000.

11.2.5 Payback

The direct payback time is:

\$50,000 / \$32,000/yr = 1.6 yrs

11.3 HVAC #3: New solutions for re-heat, Building 655

11.3.1 Existing conditions

Many buildings at West Point have reheat HVAC systems and in an effort to conserve energy, the amount of reheat energy being used is greatly reduced or eliminated. These systems were installed many years ago and the reheat is needed to bring the conditioned air up to warmer temperatures to avoid adversely cold spaces in the summer. This cold air is an indoor air quality (IAQ) and indoor environmental quality (IEQ) (mold) concern. With this minimum of reheat energy, a number of spaces are in the mid to upper 60 °F temperature. Such cold temperatures, in addition to being uncomfortable, create an environment susceptible to mold growth. If there is significant mold growth, the energy savings obtained by avoiding reheat would be spent several fold on mold clean-up. These cold temperatures

were observed in the West Point Club, Hotel Thayer, and Eisenhower Hall. Building 655, Eisenhower Hall, is used as an example for demonstrating the benefits of this ECM.

Eisenhower Hall is a 338,000 sq ft facility that houses a large auditorium, ballroom and other spaces used for social events. These spaces are heated and cooled by six air-conditioning units having a total air flow of more than 200,000 cfm. Cooling is obtained by local chillers and heating energy is provided by the site central steam system. These air-conditioning systems operate continuously even though most of the building spaces are used less than 25 percent of the time. This results in spaces that are quite cold. There is evidence of moisture on ceiling tiles and walls of rooms.

The spaces these HVAC systems serve often have varying levels of use such that the amount of internal heat generated changes significantly from levels of high use to periods of non-use. This causes drastic changes in the amount of reheat required and if not provided, spaces end up uncomfortably cold.

11.3.2 Solution

Some type of reheat is needed in this building because the cold spaces cause other problems since water vapor condenses on the cold surfaces, creating conditions for mold growth. But the energy used for reheating is considered a waste and should be avoided or at least minimized. There are two actions that should take place. First, the constant volume systems should be changed to a variable air volume (VAV) type. This will enable the air-conditioning system to track the varying loads by changing air volume rather than adding or removing reheat energy. Second, find an acceptable waste heat source for the reheat energy and are listed below. This allows the current HVAC systems or those modified to VAV to continue to operate as designed with little purchased energy being devoted to reheating the air. These options are:

- HVAC #3A: Use cooling system condenser heat
- HVAC #3B: Use heat exchanger to transfer heat from return air to supply air
- HVAC #3C: Provide an air bypass around the cooling coil

Table 24 lists the six air-conditioning systems service the spaces shown. From the observations made during the site visit, these systems operate continuously with no adjustment to operation during the unoccupied hours. All air-conditioning systems are candidates for a VAV system except AC No. 3, which serves the snack bar and its kitchen area. The kitchen has a 19,000 cfm exhaust requirement, which is approximately 2/3 the supply air amount. The VAV system would include variable speed motors for the supply and return fans. Variable air flow duct boxes will be added to all zones before their reheat coils except for AC Unit N0s. 2 and 6. AC Unit No. 2 is a single zone system allowing flow adjustment at the air handling unit. AC Unit 6 is multi-zone air-conditioning systems whose hot and cold deck dampers will be modified to provide a variable air flow. A static pressure sensor will be placed in the main air duct to monitor the desired rate of air flow, which will be used to control the speed of the variable speed fan motors. With the VAV system the space thermostats will maintain the desired space temperatures by varying the air flow. If there is no one in a space, the internal heat being generated in the space is low and therefore, a lower amount of cool air is required to satisfy the desired room temperature. With a lower amount of air being supplied less reheat energy is needed to satisfy the thermostat.

Table 24. Air-conditioning systems service the spaces in Building 655.

Air Conditioning System	Spaces Served	Type System	Air Flow, cfm
1	Auditorium Stage Area	Multi-space Reheat	30,245
2	Auditorium	Single Zone Reheat	45,100
3	Snack Bar & Kitchen Areas	Multi-zone	29,800
4	Ball Room	Multi-space Reheat	35,500
5	Grand Hall & Misc. Spaces	Multi-space Reheat	65,750
6	Auditorium Balcony Spaces	Multi-zone	37,500

11.4 HVAC #3A

Of the options for the reheat energy, using condenser water from the chillers is the most attractive. The cooling system condenser water from the chillers would be piped to the reheat coils and the condenser heat used to reheat the air-conditioned air. This option would require specially design chillers having a double bundle condenser section (Figure 42). This type of condenser includes a heat recovery condenser that can be piped to the re-

heat coils without modifying the refrigerant cooling elements of the machine. The condenser water is cooled in the heat recovery section and in the normal condenser section, which is cooled by cooling water. Water temperatures in the heat recovery section range from 120 °F to 140 °F are available with this approach. It is understood that new chillers are on order for this building, but it is unlikely that they will have the double bundle option. The same affect may be accomplished by modifying the condenser water piping so that the warmest water first flows to the reheat coils. The existing coils will need to be supplemented with an additional coil to obtain the required larger coil surface since the supply water temperature will be lower. This new coil would be placed immediately after the existing reheat coils. The supply air duct will need to be slightly modified to accept this new coil. The existing piping and pumps should not need modification for this action.

11.5 HVAC #3B

Another option for obtaining free reheat energy would be to install a run-a-round type of heat recovery system, which would raise the supply air temperature while lowering the incoming air temperature to the air-conditioning unit. With this system, coils would be placed in the return air stream just before the air enters the air handling unit and the existing reheat coils would be supplemented in the same way as the option using warm condenser water (Figure 43).

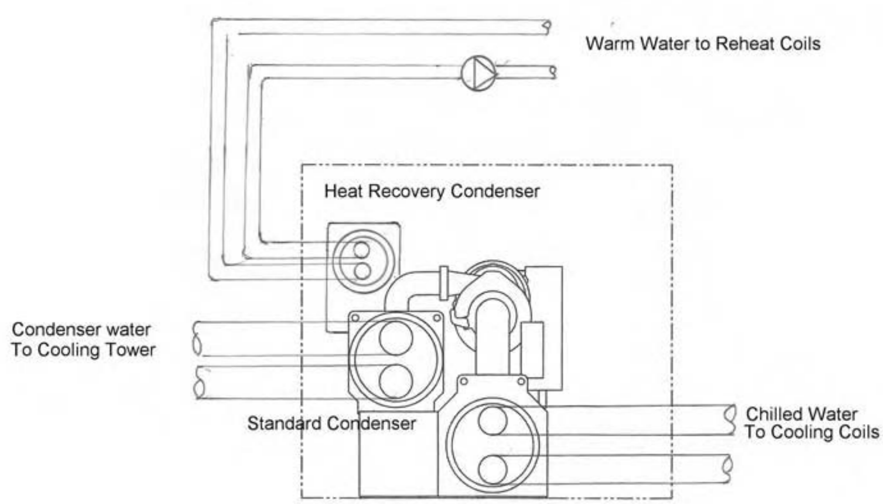

Figure 42. Chiller with double bundle condenser to provide warm water to reheat coils.

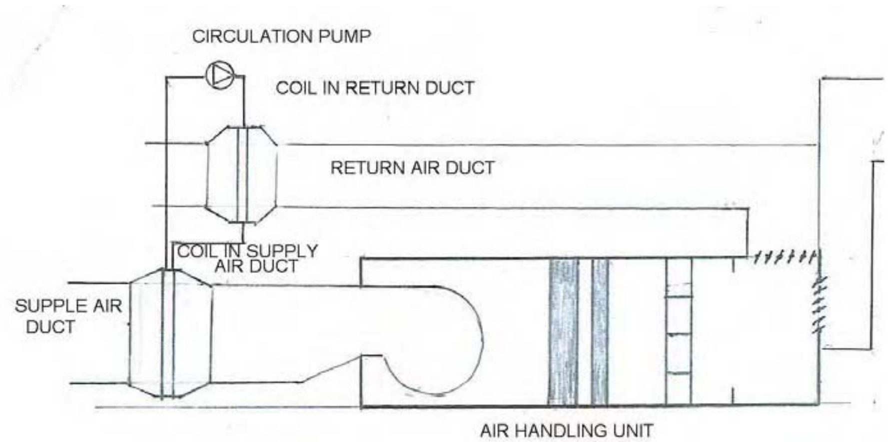

Figure 43. Air handling unit with heat transfer coil.

The return air to the air-conditioning system should have a temperature in the range of 75 to 85 °F, which would provide a 70 to 75 °F heating water. The existing hot water pumps and piping between the coils will be used. New piping will be needed to the coiled placed in the return ducts. The return and the supply air duct work will need modification to accept the new coils. A duct transition section will be required to insert the coil section in the return ducts. A benefit of this approach is that cooling the air will become more efficient since a lower air temperature will be entering the air handling unit's cooling coil since heat was removed for reheat energy.

11.6 HVAC #3C

The last option is a similar approach to the run-a-round approach, but an air by-pass at the air handling unit would be used (Figure 44). Some of the return air would be mixed with air that had passed through the cooling coil to raise the leaving air temperature. For example, using a return air temperature of 75 °F, about half the return air would be mixed with cooled supply air to bring air leaving the cooling coil up from 55 °F to 65 °F.

In this case, the cooling coil would be seeing less air (rather than cooler air), which will also reduce the loading on the chiller. To implement this option, a face and by-pass coil section would need to be added to the air handling unit. This will require a larger cross section than one required by the cooling coil. It would be very difficult to modify an existing air handling unit to provide this type of coil section, but AC Unit 6 already has this ability since it is a multi-zone unit.

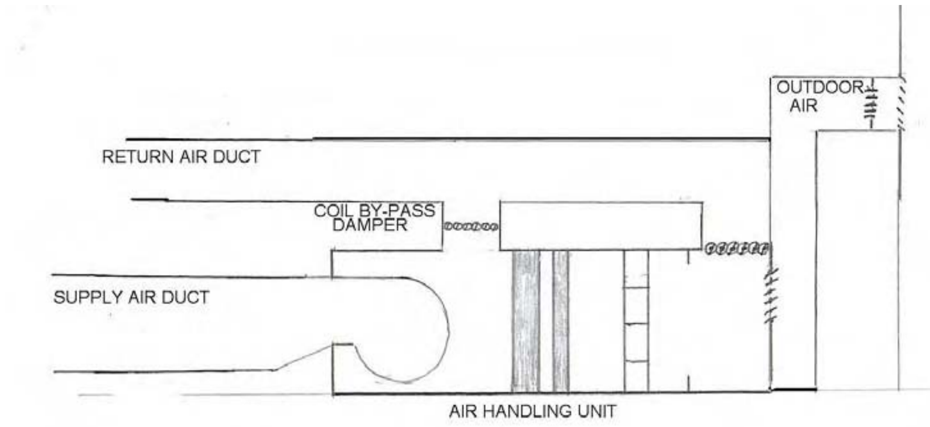

Figure 44. Air handling unit with cooling coil by-pass.

For the others, it may be possible to provide a return air connection to the fan plenum. For the others the modification would be a cross connection between the return air duct and an opening placed in the fan plenum. A set of dampers would be placed in this cross connection to vary the amount of by-passed air to suit conditions.

Allowing these air handling units to continue to operate as they do will result in additional energy waste, uncomfortable temperatures, and the creation of an environment that promotes mold growth.

11.6.1 Energy Savings

11.6.2 VAV System (Applies to HVAC #3A, HVAC #3B, and HVAC #3C)

The reduced air flow provided by the VAV system would occur when the auditorium, Grand Hall, and other spaces are not used to their maximum capacity. Since the spaces in Eisenhower Hall are in use less than 25 percent of the time during operating hours, this is an estimated 84 hrs/wk. The VAV operation will reduce air flow to approximately 40 percent of the original flow during these times. During the off hours, the flow could be reduced to 30 percent of normal flow. This air flow reduction will provide a fan horsepower savings of more than 80 percent. The energy use of an air distribution system when the air flow is reduced varies to the cube of the per flow reduction. The cube of 30 percent is approximately 3 percent. A certain amount of fixed losses in a motor are relatively constant so a value of 80 percent reduced energy use was chosen. The total brake horse power of the five supply fans and five return air fans is 169 HP and 43.4 HP respectively.

Assuming these fans operate 24 hrs/day, then the total fan electrical use savings is 126 kW for a savings of electrical use of 1.1 million kWh/yr. The cooling energy saving during the reduced air flow will result from the reduced outside air load and the reduced fan horsepower heat experienced by the cooling coil. This is estimated to be 10 percent of the cooling energy use, which amounts to 5,000 kWh/yr. Savings are calculated as:

Fan HP savings = (169 + 43.4) Hp X 80% X 0.746kW/hp X 8760 hr/yr = 1,100,000 kWh/yr

Chiller savings = 700 tons X 500 EFLH X 10% X 1kW/ton-hr = 35,000 kWh/yr

Total Electrical Savings = 1,135,000 kWh/yr

11.6.3 Electrical Cost Savings

Electrical Savings are calculated as:

Electrical cost savings = 1,135,000 kWh X $0.125/kWh = $142,000/yr

Natural gas fuel savings will result from reduced reheat by the same amount that the air flow is reduced or an average of 65 percent. This occurs during the 5 month nonheating season. Since many of the spaces were cold, it is felt additional reheat should be used to make these spaces warmer; this would increase the reheat used by approximately 35 percent resulting in an estimated reheat savings of 30 percent. This equals a heating energy savings of 151 million Btu/yr, which results in a natural gas savings of 216 million Btu/yr considering a 74 percent boiler efficiency:

Heating energy savings = 1.08 X 214,000 cfm X 5 °F X 5 months X 30 days X 24hrs/day X 30%/74%

= 1,687 Million Btu/yr

Natural gas cost savings = 1,687 Million Btu/1000 X $12.39/million Btu = $20,900/yr

Total cost savings for installing VAV in Building 655 = $158,400/yr

11.6.3.1 HVAC #3A

The reheat heating cost is estimated to be $14,600/yr assuming an average reheat of 3 °F. This savings is after a VAV system is initiated where the air flow is reduced to an average 35 percent of the original flow during the 5-month cooling season:

Q = 1.08 X 3 °F (35% X 214,000 cfm) X 5 months X 30 days X 24hrs/day X /74%

= 1,180 Million Btu

Natural gas cost savings = 1,180 Million BH/1000 X $12.39/million Btu = $14,600/yr

The option to use chiller condenser heat for reheat will use the condenser water pumps. The pressure drop through the supplemental reheat coil will be minimal.

11.6.3.2 HVAC #3B

The option to use heat exchangers to transfer heat from return air to supply air with a coil run-around system would require coils to be placed in the return air duct. The placing of these heating coils would also increase the fan energy use due to their resistance to air flow. It is estimated the coils would increase the static pressure of the air distribution by 0.15 in. wg. The resulting electrical added energy use by the fans is estimated to be 6,800 kWh per cooling season. The existing hot water pumps would be used to circulate this water rather than using generated hot water from steam. No additional pumping energy use will occur.

Additional Fan Energy Use = 214,000 cfm X 35% X 0.15 in./(6362 X 0.7 fan eff.) X 0.746 kW/Hp X 150 days/yr X 24 hr/day = 1.9 kW X 3600 hrs/yr = 6,800 kWh/yr

Electrical Increased Cost = 6,800 kWh/yr X $0.125 = $850/yr

The total energy savings of this option then becomes $13,750/yr.

HVAC #3C

The next option, which would provide an air bypass around the air handling unit's cooling coil, would also not require new chillers. The return air would mix with the chilled air providing an appropriate air temperature. The avoided reheat energy savings would be same as the other options equaling $14,600/yr. There is no pump and additional coils required so there is no additional electrical use with this approach.

11.6.4 Investment

To achieve the VAV type control in Building 655, variable speed controls will need to be installed on all the fan motors. Controls will need to be added that will sense space temperature and humidity and adjust the fan motor speed to increase or reduce the air flow as cooling is required. For the individual spaces having reheat coils, new variable air flow boxes or air flow dampers will be installed. The total estimated cost for these additions is $187,000.

11.6.4.1 HVAC #3A

The condenser heat recovery option is best done with new chillers. It was noticed during the site visit that a temporary chiller was cooling the building and a new chiller system is planned for installation this winter. Since this chiller has already been specified, it is unlikely it will have a double bundle condenser type construction. To use the normal temperature condenser water, a supplemental reheat coil behind each of the reheat coils will be required. The estimated cost of these coils plus valves, piping and installation is $136,000.

11.6.4.2 HVAC #3B

The run-around coil system would require a set of coils placed in the return air duct. The cost for this work will include the coils, duct modifications to install the coils, piping, and controls. The existing heating pumps will be used. The estimated cost of these items placed in the return air ducts is $160,000. The modifications required to the reheat piping system needed in the condenser heat recovery option are also required with this one. The total estimated for the run-around coil system is $296,000.

11.6.4.3 HVAC #3C

The cooling coil bypass system can be easily accomplished with multi-zone air handler units, which are the type of AC unit No. 6. The other units will require ductwork modifications for the installation of a cross connection from the return air duct to the fan plenum in the air handling unit. The installation of this cross connection will greatly reduce the required reheat energy used for AC units 1, 4 and 5. It will completely eliminate the reheat energy used by AC 2 since it is single zone system. The other systems use the reheat coil to adjust the temperature leaving the air handling unit to suit the zone conditions. The estimated cost of this modification is $1.00/cfm for a total cost of $130,000.

11.6.5 Payback

The payback of the VAV system conversion combined with re-heat (3 Options) is:

- HVAC #3A (VAV conversion and condenser water re-heat):
  $323K/$177.4K = 1.8 yrs
- HVAC #3B (VAV conversion and Run-around coil re-heat):

$483K/$177.6K = 2.7 yrs

- HVAC #3C (VAV conversion and Cooling coil bypass re-heat):
  $317K/$177.6K = 1.8 yrs.

11.7 HVAC #4: Re-commissioning of HVAC systems and controls

11.7.1 Existing conditions

Most buildings at West Point have pneumatic controls for AHUs, radiator heating and cooling networks, fan coils, and VAV-units. Most of the systems are on remote control, setpoint adjustments and operating schedules are changed from the Building Management System (BMS) monitoring room at the boiler plant. The pneumatic controls are operated via electro-pneumatic transformers changing the signal from the BMS into pneumatic actuator functions. The equipment is mainly quite old; many valves and actuators are 30–40 yrs old. The controls need intensive maintenance and the sensors are calibrated once a year.

During the site visit the following observations were made:

- Most AHUs run 24/7.
- Night time and weekend temperature setback is not used.
- Some systems have very low supply air or room temperature setpoints for cooling season.
- Some systems show inconsistent temperature values (return air cooler than supply).
- Some valve actuators are not in the position the system shows (temperature level does not match the shown valve position).
- Setpoint changes are made frequently based on occupant complaints, the actual effect of the change may not change indoor conditions, but will affect energy use.
- Some of the controls were inoperative.
- In some buildings the pneumatic piping leaks and holding adequate pressure level is not possible.

The present operation wastes heating and cooling energy, compressor usage, and fan electricity. Additionally, cold supply air and excessive heat leads to complaints from building occupants.

11.7.2 Solution

The control system should be re-commissioned. This means re-adjusting the electro-pneumatic transformers and pneumatics, calibrating sensors, ensuring that all valve and damper actuators operate correctly, and ensuring that all values shown on the BMS computer screen are true.

All temperatures setpoints should be consistent with each other and proper for the specific building or AHU service area. Setpoint dead bands between heating and cooling should be adjusted so that simultaneous heating and cooling is not possible. All economizer modes on AHUs should be checked. Time schedules should be adjusted to meet building specific needs. This should be done on a continuous basis to take into account the irregular use of some spaces and buildings.

11.7.3 Savings

Savings would be specific to each building and air handler unit. Savings would come from fan energy and heating and cooling savings if operation times and setpoints are changed and setback temperatures taken into use.

Some examples of savings from reduced running time for a typical AHU:

Outside air flow: 4 m^3/s = 8,475 cfm

Average OA temperature during heating season: 4.6 °C = 40 °F

Average supply air temperature is about 20 °C = 68 °F

Extract air temperature about 22 °C = 72 °F

Average return air 50%

Fan size 15 kW = 20 hp (supply and return motor input power)

Hours of operation before: 8760 hrs/yr

Hours of operation after: 3760 hrs/yr

Hours of unnecessary operation: 5000 hrs/yr, 2900 hrs during the heating season

Savings in heating energy 110 MWh/yr = 3,750 therm/yr = $5,900 /yr (80% thermal efficiency)

Savings in fan electricity 75 MWh/yr = $9,400 / yr

Average OA enthalpy during summer months 52 kJ/kg

Average supply air enthalpy during summer months 42 kJ/kg

Chiller COP 3.5

Savings in cooling energy (electricity) 30 MWh/yr = $3,800 / yr

Total savings $19,100 /yr.

11.7.4 Investments

The costs of re-commissioning would also be specific to each system and AHU, depending on the complexity of the controls and number of VAV boxes in the system, etc.

The re-commissioning per building may take two persons 2 days to check everything. If the total amount of work for re-commissioning all the major buildings and systems is estimated, it would cover approximately 50 buildings, 30 chillers, 150 AHUs. This would lead to a total of 1600 work-hours (100 working days for two people).

If the cost of commissioning expert work is $100/hr, the cost per building is roughly $3,500–$4,000. The savings from AHUs will cover the cost. Post-wide the cost is $160,000–$200,000.

11.7.5 Payback

As with savings and investment, payback would be specific to each air handler unit. Immediate payback is expected. For the example air handling unit, the payback time is less than 0.2 yrs.

11.8 HVAC #5: Use existing steam absorption chiller and supplement with small electric chiller at KAH

11.8.1 Existing conditions and problems

At KAH, Bldg 900, there is one 243-ton Trane absorption chiller in the mechanical room in the basement. The chiller is run on steam supplied from the central energy plant located at the laundry, building no 845. Supply is available all year around since the hospital needs steam also for sterilization (clean steam generator in the basement, driven by steam from the laundry) and domestic hot water.

There is also a 300-ton York electric chiller that is used at present. It has the capacity to air-condition the entire building. The absorption chiller capacity is not sufficient to do the same job. The electric chiller runs at its maximum during hot days.

The Building 900 Renovation Priority List, shows one project named, “Replace Chiller,” which denotes replacing the existing electric chiller with a new electric chiller. There seems to be a trend at West Point to replace absorption chillers with electric chillers, but without an economic analysis, it is impossible to say if this is optimal. The cost of 12.5 cents/KWh makes it unlikely, especially where steam adsorption chillers exist.

11.8.2 Solution

Use the existing steam absorption chiller as the base load chiller. Supplement with a small electric chiller, approximately 80 – 90 percent to capacity to give a total capacity of 330 tons (10 percent more than the present electric chiller has). Run these chillers, absorption and new small electric, in series so that the electric chiller can take care of only the peak load while the absorption chiller runs most of the time and as loaded as possible.

11.8.3 Savings

There are two types of savings:

1. *Reduced investment costs*: If a new electric chiller is estimated to cost $604k, a small electric chiller may reduce the investment by $300k.
2. *Reduced operational costs*. Running the absorption chiller instead of having most of the cooling load on the electric chiller will be cost efficient.

11.8.4 Investment

No additional investment. Negative investment cost.

11.8.5 Payback

Simple payback will occur immediately.

11.9 HVAC #6 Switch off boilers in Holleder Center; Use local gas burners to regenerate desiccant wheel in de-humidifier

11.9.1 Existing conditions and problems

At the ice hockey rink in the Holleder Center (a facility that also contains a large basketball court) there is a need for dehumidification. A 7,500 cfm dehumidification unit (year 2000 vintage) with a desiccant wheel is lo-

cated at the mechanical platform, north side of the rink. The Holleder Center has ice year around, and as a consequence there is also a need to run the dehumidification unit all year around. This also requires an operational heating system with one natural gas-fired boiler running, and a heat distribution throughout the entire center at 180 °F, so that heat circulates through heating coils also in the basketball arena, using a 40 hp motor for heat circulation. Heat circulates through both boilers, with stack losses through both, even though only a fraction of one boiler's capacity is needed in summertime. In summary, there is a large waste of energy for a very small supply (to the desiccant wheel) that can easily be supplied locally using a small gas burner.

During our visit, and inspecting the EMCS where most of the Holleder Center mechanical equipment is connected, it was observed that the Hot Water (HW) supply temperature was 174 ˚F while the return temperature was 170 ˚F (Sept. 27, 2007). Most of the energy then is losses in the heat distribution system.

11.9.2 Consequences of present situation

Heat through heating coils in AHUs that supply basketball court makes the basketball arena unnecessarily warm.

The space temperature in the mechanical rooms in the evening of Sept. 26 was 100 °F. These high temperatures are not recommended in rooms with electrical and electronic equipment. Heat circulating pumps were running—not only the large 40 hp motor in the boiler room, but also smaller pumps/pump motors in the AHUs.

11.9.3 Solution

Replace the HW coil in the dehumidification unit reactivation heater with a direct-fired burner. (One manufacturer, DHI, is reachable at www.dhihvac.com. The unit model # is DH-148-7.5-HW-OT. From product data documents it was found that this unit either comes with a HW coil or with a direct-fired burner)

11.9.4 Savings

It will be possible to switch off the gas boilers totally from 15 April to 15 October in normal years if the proposed solution is adopted. With the low heat load in summer, the boiler in operation also runs at very low energy efficiency. From the FEDS results for building set 80f, where Bldg 714 is included, an average use of fuels (gas, fuel oil etc.) sums up to 24 MMBTU/1,000 sq ft. For Holleder Center, which is 131,000 sq ft, this translates to more than 3,100 MMBTU. After having seen the actual present way of running the systems, it is safe to believe that at least 30 percent of the annual gas use at Holleder Center is used from 15 April to 15 October. Switching the boilers off will thus generate savings of approximately 900 MMBTU annually, worth $11k.

Switching off the boilers will also reduce the electricity use by the large motor. Assume that the motor is 50 percent loaded, using 20 hp continuously for the 6 months. Annual savings by switching it off are:

20 hp * 0.746 kW/hp * 180 days * 24 hrs/ day = 64,500 kWh worth over $8,000.

11.9.5 Investment

Investments are estimated to be $10K.

11.9.6 Payback

Simple payback will occur in less than 0.5 year, easily within the first summer of operation (within a year on switching off the heat circulation pump only).

11.10 HVAC #7: Use waste heat from ice makers / use condenser heat in the Holleder Building to pre-heat outdoor air

11.10.1 Existing conditions and problems

The Holleder Center has a large compressor mechanical room, where the compressors for cooling the ice are located. The compressors have 2 * 100 hp motors as prime movers. The system contains 1,500 lbs of R-22. The system produces ice all year around. The excess heat is pumped to a cooling tower right above the compressor room where the heat is cooled off to

the atmosphere. The temperature in the cooling tower is in the range of 80–85 °F.

During the heating season, there is a need for heat within the Holleder Center. This need is for heating the premises in the Air Handling Units and by baseboard heating. This heating is done by using two natural gas-fired boilers, both rated at 14,848 MBTU/hr.

The need for heat is large in the winter. However, this is also the time of year when the excess heat is at its lowest level.

11.10.2 Solution

Consider using the excess heat from the ice compressors to generate heat that can be used to pre-heat domestic hot water, water to be used for ice maintenance and for pre-heating the OA to the AHUs. This will require a more detailed study to get more data on compressor operation (load duration), temperatures, design data on present coils in AHUs and possibilities to use these coils or to install new sets of coils etc. To be able to use the low temperature heat from the compressors, it might also be necessary to install a heat pump to increase the temperatures.

11.10.3 Savings

It is believed that the Holleder Center could have most of the heat supplied from the ice compressors, i.e., 3,100 – 900 = 2,200 MMBTU after having switched off the boilers during the summer period, see ECM HVAC#10 above. Assume that annual savings of 2,000 MMBtus worth $25 k can be achieved.

11.10.4 Investment

It is not possible to determine required investments at this stage.

11.10.5 Payback

It is not possible to calculate simple payback.

11.10.6 General recommendation for energy efficiency in ice arena

Keep the hall temperature as low as possible, especially during unoccupied periods. The lowest recommended temperature is +5 °C. If night time setback temperature is too low, there may be fog in the hall in the morning when outdoor humidity is high. Temperature level may be higher for humid weather conditions. The effect on cooling (ice making) electricity demand is 28–38 MWh/°C (per degree of hall room temperature) when the temperature range is from –1 to +20 °C. For heating energy demand, the effect is 80 MWh/°C (per degree of hall temperature).

The supply air flow (amount of outdoor air) should not be too high, because the outdoor humidity increases cooling load. During practice events, 12 liters/s per player is needed, during games 4–8 liters/s per person (spectators).

Keep the ice temperature as high as possible. A recommended temperature for ice hockey use is –3 °C (during tournaments –5 °C may be used). A night time setback temperature may be used, during unoccupied periods, -1 °C in ice temperature may be allowed. The effect on electricity use is 55–65 MWh/ °C (per degree centigrade in ice temperature) when the temperature range is –1 to –6 °C. Ice surface temperature measurement is the best for controlling the temperature of the ice, better than measuring the return fluid temperature from the glycol pipes under the ice. The thickness of the ice has some effect on the energy use. In ice maintenance, the amount of water and the water temperature should be as low as possible. Typically 400–800 liters of water is used per maintenance round (meaning the time when the machine is on the ice), the water temperature is usually around +30 °C. Condensing heat from the ice-making machines could be used for warming up the maintenance water as the condensing temperature is usually too low for pre-heating domestic hot water.

The dehumidifying systems can be turned off during winter months when the outdoor humidity is low and no humidity load is brought in by the ventilation system. The relative humidity setpoint could be as high as 75 percent. (Earlier, 50–55 percent has been used, but this is not necessary.) The humidity sensors should be calibrated yearly. Unnecessary lighting should be avoided, because it increases the need for cooling. Usually the heating demand, domestic hot water heating demand and ice maintenance hot wa-

ter heating demand can be covered by using the heat from ice making machinery. The problem is usually the low temperature level of the condensing liquid.

11.11 HVAC #8: Do not replace AHUs at KAH

11.11.1 Existing conditions and problems

KAH was built in 1976. There is an ongoing (or just planned) renovation project with a priority list describing different projects in priorities graded from 1 to 3. The total project is estimated to be in the range of $10 million. Of this amount, a total of $704,000 is aimed at replacing AHUs 1–4 with new units.

The assessment included a tour through the hospital and also the mechanical rooms in the basement. The general impression is that the AHUs are in a fairly good shape. They need upgrading; they should be modernized according to the proposed solution described below.

11.11.2 Solution

Use $50 k/AHU for the following more urgent needs:

- Replace all damper actuators and motors. Make sure dampers work smoothly.
- Replace fans and fan motors. Make sure that the fans match the needed flow and pressure and make sure that the motors are energy efficient.
- Replace VFDs that do no longer work. See also proposal C-4 above.
- Check controls, static pressure setpoints and sensors, see Texas A&M report regarding "continuous commissioning." Replace faulty sensors. Re-program controls for proper functions.

11.11.3 Savings

The avoided investment (the savings in this case) is:

$704 k – (4 * 50 k) = $500 k

11.11.4 Investment

In this case, avoid investment. Use as much as possible of the existing AHUs; replace the essential parts and make sure they work.

11.11.5 Payback

Simple payback will occur immediately.

11.12 HVAC #9: Install CO_2 controls in KAH

11.12.1 Existing conditions and problems

As described at the end of ECM # C-3b the AHUs at KAH run 24/7 at 100 percent OA. The proposed solution in C-3 was to run only parts of the ventilation system during unoccupied hours and supply conditioned fresh air to parts of the hospital that are manned and/or occupied during other times than daytime. That left a system running with approximately 140,000 cfm during 45 hrs/wk and with 30,000 cfm during 123 hrs/wk, still all at 100 percent OA. Supplying 100 percent outside air is expensive both to heat and to cool.

11.12.2 Solution

Install CO_2 sensors at selected spots around the hospital, normally where the temperature sensors are placed. Modulate OA dampers and return air dampers so that the maximum CO_2 level is not exceeded. It is believed that a limit of 800 ppm is acceptable. Above that level the OA damper opens to 100 percent OA, below that level the OA can go down to minimum level (proposed to be 20 percent OA or around that ratio).

11.12.3 Savings

Normal savings with CO_2 control vary with type of building and type of activities within a building. Assuming that the CO_2 control leads to a system that on average runs at 50 percent OA instead of 100 percent gives the following savings. (For more details see C-3.)

11.12.3.1 Heating

Reduce outside air flow by 70,000 cfm (33 m^3/s) during 45 hrs/wk or an average of 6.5 hrs/day for 7 days/wk and by 15,000 cfm (7 m^3/s) during the remaining 123 hrs/wk or an average of:

17.5 hrs/wk: 33 m^3/s * 1.2 kJ/kg, °C * 3,313 degree-days C* 6.5 + 7 m^3/s * 1.2 kJ/kg, °C * 1.0 kg/m^3 * 3,313 degree-days C * 17.5 hrs/day = 1,340,000 kWh = 4,600 MMBtus/yr net.

With 70 % boiler efficiency the gas use comes to 4,600/0.7 = 6, 600 MMBtus/yr worth $82 k. (Gas price = 12.39 $/MMBtu.)

11.12.3.2 Cooling

33 m^3/s * 1.2 kJ/kg, °C * 1.0 kg/m^3 * 419 degree-days * 6.5 hrs /3.0 + 7 m^3/s * 1.2 kJ/kg, °C * 1.0 kg/m^3 * 419 degree-days * 17.5 hrs /3.0 = 56,000 kWh worth $7k/yr. (COP = 3.0)

Total savings: $89 k/yr.

11.12.4 Investment

The approximate cost is $100k, which includes CO_2 sensors, installation of sensors, new wiring for sensors, and re-programming controls for the AHUs to work according to the new control strategy.

11.12.5 Payback

Simple payback will occur within 14 months.

11.12.6 Comments

Observe that this ECM gives savings in addition to the proposed reduction of operating hours, ECM CON #2.

11.13 HVAC#10: Replace existing boilers with new efficient boilers

11.13.1 Existing conditions and problems

Some boilers on site are old and inefficient, with efficiencies ranging from 66 to 77 percent.

11.13.2 Current technology

Current technologies are natural gas and other-fueled conventional boilers.

11.13.3 Recommended solution

It is recommended to”

- Replace older boilers with new natural gas or liquid petroleum gas (LPG) boilers, with efficiencies ranging from 84 to 91 percent.
- Replace existing gas boilers with more efficient condensing natural gas boilers.
- Replace existing gas boilers with more efficient non-condensing natural gas boilers.
- Replace existing propane boilers with more efficient non-condensing LPG boilers.

11.13.4 Energy savings

Replacing existing boilers with new more efficient natural gas or LPG boilers would save 3,528 MMBtu/yr, according to FEDS calculations. This is a savings of $94,973/yr.

11.13.5 Additional benefits

Maintenance cost savings will be $2,879/yr with new boilers.

11.13.6 Investment

The new systems and their installation costs $404,626.

11.13.7 Payback

Simple payback will occur in 4.1 yrs.

11.14 HVAC #11: Replace forced air heating with radiant heating

11.14.1 Existing conditions and problems

A number of large warehouses or high bay spaces have forced air heating. This type of system in these buildings tends to be inefficient for primarily two reasons. First of all, the ceilings are high to allow tall equipment use, but the occupants remain on the ground. The heated air rises, leaving the occupants on the ground uncomfortably cold and therefore more heat is needed. Secondly, large roll-up doors are used frequently and often do not close tightly, allowing heated air to escape. Windows often cover the tall

walls to allow daylight to enter, but these are often old and cracked, and/or cannot close.

11.14.2 Current technology

Current technologies used are local combustion boilers or central steam boilers that provide hot water or steam to air handling units and fan coil units, and local forced air furnaces.

11.14.3 Recommended solution

Heating units that do not heat the air would eliminate heat loss through infiltration and through rising warm air. IR heaters provide heat directly to objects, warming occupants and surfaces instead of the surrounding air (Table 27). These warehouses would be an ideal location for IR heating, replacing building level boilers with fan-coil units and conventional forced air furnaces with IR heaters. Industrial buildings with smaller rooms used as shops or other small industrial uses have lower ceilings and will use electric radiant heating, which is a better application for close quarters (Table 28).

11.14.4 Energy savings

Replacing the forced air heating systems with IR heating systems would save 5,099 MMBtu/yr, according to FEDS calculations. This is a cost savings of $99,801/yr (Table 29).

11.14.5 Additional benefits

Switching to IR heating incurs a maintenance cost of $8,582/yr.

11.14.6 Investment

This ECM would cost $365,931 to implement.

11.14.7 Payback

Simple payback will occur in 3.4 yrs.

Table 25. Summary of HVAC #10a: Replace existing gas boilers with more efficient condensing natural gas boilers.

ECM #	ECM Description	Electrical Savings			Thermal		Plant Energy Savings		Maintenance	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint	Investment	Simple Payback
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr	MBtu/yr	$/yr	$/yr	$/yr	$	yrs
HVAC_10A	Replace Existing Boiler with Condensing Gas Boiler – 91% Combustion Efficiency	0	0	$–	0	$8,901	$–	$–	$(132)	$8,769	$60,457	6.9
HVAC_10B	Replace Existing Boiler with Condensing Gas Boiler – 91% Combustion Efficiency	0	0	$–	0	$8,766	$–	$–	$(257)	$8,509	$49,286	5.8
HVAC_10C	Replace Existing Boiler with Condensing Gas Boiler – 91% Combustion Efficiency	1	0	$27	27	$29,003	$–	$–	$(998)	$28,032	$70,449	2.5
Totals		*1*	*0*	*27*	*27*	*46,670*	*0*	*0*	*–1,387*	*45,310*	*180,192*	*4.0*

Table 26. Summary of HVAC #10b: Replace existing gas boilers with more efficient non-condensing natural gas boilers.

ECM #	ECM Description	Electrical Savings			Thermal		Plant Energy Savings		Maintenance	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint	Investment	Simple Payback
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr	MBtu/yr	$/yr	$/yr	$/yr	$	yrs
HVAC_10D	Replace Existing Boiler with Conventional Gas Boiler – 84% Combustion Efficiency	0	0	$–	0	$2,554	$–	$–	$1,815	$4,369	$48,301	11.1
HVAC_10E	Replace Existing Boiler with Conventional Gas Boiler – 84% Combustion Efficiency	0	0	$–	0	$2,178	$–	$–	$27	$2,205	$16,485	7.5
HVAC_10F	Replace Existing Boiler with Conventional Gas Boiler – 84% Combustion Efficiency	0	0	$–	0	$1,313	$–	$–	$268	$1,581	$9,190	5.8
HVAC_10G	Replace Existing Boiler with Conventional Gas Boiler – 84% Combustion Efficiency	0	0	$–	0	$13,527	$–	$–	$402	$13,929	$33,628	2.4
HVAC_10H	Replace Existing Boiler with Conventional Gas Boiler – 84% Combustion Efficiency	0	0	$–	0	$9,686	$–	$–	$590	$10,276	$32,190	3.1
HVAC_10I	Replace Existing Boiler with Conventional Gas Boiler – 84% Combustion Efficiency	0	0	$–	0	$2,373	$–	$–	$29	$2,402	$5,258	2.2
HVAC_10J	Replace Existing Boiler with Conventional Gas Boiler – 84% Combustion Efficiency	0	0	$–	0	$5,568	$–	$–	$251	$5,819	$13,326	2.3
Totals		*0*	*0*	*0*	*0*	*37,199*	*0*	*0*	*3,382*	*40,581*	*158,378*	*3.9*

Table 27. Summary of HVAC #10c: Replace existing propane boilers with more efficient non-condensing LPG boilers.

ECM #	ECM Description	Electrical Savings			Thermal		Plant Energy Savings		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr	MBtu/yr	$/yr				
HVAC_10K	Replace Existing Boiler with Conventional LPG Boiler – 84% Combustion Efficiency	0	0	$–	0	$11,079	$–	$–	$884	$11,963	$66,056	5.5

Table 28. Summary of HVAC #11a: Replace existing propane boilers with high efficiency LPG infrared heating system.

ECM #	ECM Description	Electrical Savings			Thermal		Plant Energy Savings		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr	MBtu/yr	$/yr				
HVAC_11A	Replace Existing Boiler with LPG Infrared Heating System – High Efficiency	0	0	$–	0	$40,467	$–	$–	$3,181	$43,648	$142,828	3.3
HVAC_11B	Replace Existing Furnace with LPG Infrared Heating System – High Efficiency	0	0	$–	0	$21,310	$–	$–	$1,141	$22,451	$104,383	4.6
Totals		*0*	*0*	*0*	*0*	*61,777*	*0*	*0*	*4,322*	*66,099*	*247,211*	*3.7*

Table 29. Summary of HVAC #11b: Replace forced air heating with high efficiency natural gas infrared heating system.

ECM #	ECM Description	Electrical Savings			Thermal		Plant Energy Savings		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr	MBtu/yr	$/yr				
HVAC_11C	Replace Existing Steam AHU with Natural Gas Infrared Heating System – High Efficiency	−5	0	$(152)	−152	$2,961	$—	$—	$(132)	$2,677	$13,223	4.9
HVAC_11D	Replace Existing Steam FCU with Natural Gas Infrared Heating System – High Efficiency	−11	0	$(346)	−346	$6,957	$—	$—	$(311)	$6,300	$31,059	4.9
HVAC_11E	Replace Existing Boiler with Natural Gas Infrared Heating System – High Efficiency	−6	0	$(189)	−189	$7,275	$—	$—	$413	$7,499	$16,606	2.2
HVAC_11F	Replace Existing Boiler with Natural Gas Infrared Heating System – Medium Efficiency	0	0	$—	0	$21,521	$—	$—	$4,290	$25,811	$57,832	2.2
Totals		*−22*	*0*	*−687*	*−687*	*38,714*	*0*	*0*	*4,260*	*42,287*	*118,720*	*2.8*

11.15 HVAC#12: Replace existing heating systems with more efficient furnaces

11.15.1 Existing conditions and problems

Some furnaces on site are old and inefficient, with efficiencies ranging from 77 to 78 percent.

11.15.2 Current technology

Current technologies are natural gas and other-fueled conventional furnaces.

11.15.3 Recommended solution

- Replace older furnaces with new natural gas and LPG condensing furnaces, with efficiencies of 92 percent.
- Replace existing gas furnace with more efficient condensing gas furnaces.
- Replace existing propane furnaces with more efficient condensing LPG furnaces.

11.15.4 Energy savings

FEDS calculates an energy savings of 3,476 MMBtu/yr, which will yield $42,133/yr in savings.

11.15.5 Additional benefits

The additional maintenance cost is $(1,726)/yr for new furnaces.

11.15.6 Investment

The new furnaces will cost $311,786, with installation.

11.15.7 Payback

Simple payback will occur in 7.7 yrs.

Table 30. Summary of HVAC #12a: Replace existing furnace with condensing gas furnace.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
HVAC_12A	Replace Existing Furnace with Condensing Gas Furnace – 92% Efficient	9	0	$312	312	$26,654	$(949)	$26,017	$177,576	6.8
HVAC_12B	Replace Existing Furnace with Condensing Gas Furnace – 92% Efficient	(114)	0	$(3,776)	–3776	$13,458	$(484)	$9,198	$87,865	9.6
Totals		*(105)*	*0*	*$(3,464)*	*–3464*	*$40,112*	*$(1,433)*	*$35,215*	*$265,441*	*7.5*

Table 31. Summary of HVAC #12b: Replace existing propane furnaces with more efficient condensing LPG furnaces.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
HVAC_12C	Replace Existing Furnace with Condensing LPG Furnace – 92% Efficient	(39)	0	$(1,314)	(1314)	$6,086	$(255)	$4,517	$40,349	8.9
HVAC_12D	Replace Existing Furnace with Condensing LPG Furnace – 92% Efficient	(5)	0	$(159)	(159)	$873	$(38)	$676	$5,996	8.9
Totals		*(44)*	*0*	*$(1,473)*	*(1473)*	*$6,959*	*$(293)*	*$5,193*	*$46,345*	*8.9*

11.16 HVAC#13: Add automatic electric dampers to existing boilers

11.16.1 Existing conditions and problems

Some furnaces on site are old and inefficient, with efficiencies ranging from 71 to 73 percent.

11.16.2 Current technology

Current technologies are natural gas and other-fueled conventional boilers without automatic electric dampers.

11.16.3 Recommended solution

Install automatic electric dampers on existing natural gas and propane boilers where found. Automatic electric dampers increase the efficiencies of existing boilers by approximately 5 percent.

11.16.4 Energy savings

FEDS calculates an energy savings of 761 MMBtu/yr. This is $9,674/yr in savings.

11.16.5 Additional benefits

The additional maintenance cost is $(175)/yr for the electric dampers.

11.16.6 Investment

The electric dampers will cost $8,740, with installation.

11.16.7 Payback

Simple payback will occur in 0.9 yrs.

Table 32. Summary of HVAC#13: Add automatic electric dampers to existing boilers.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
HVAC_13A	Add Automatic Electric Damper to Existing Boilers	0	0	$—	0	$1,449	$(15)	$1,434	$771	0.5
HVAC_13B	Add Automatic Electric Damper to Existing Boilers	0	0	$—	0	$569	$(5)	$564	$248	0.4
HVAC_13C	Add Automatic Electric Damper to Existing Boilers	0	0	$—	0	$2,840	$(62)	$2,778	$3,095	1.1
HVAC_13D	Add Automatic Electric Damper to Existing Boilers	0	0	$—	0	$3,014	$(26)	$2,988	$1,290	0.4
HVAC_13E	Add Automatic Electric Damper to Existing Boilers	0	0	$—	0	$999	$(44)	$955	$2,184	2.3
HVAC_13F	Add Automatic Electric Damper to Existing Boilers	0	0	$—	0	$45	$(1)	$44	$31	0.7
HVAC_13G	Add Automatic Electric Damper to Existing Boilers	0	0	$—	0	$758	$(22)	$736	$1,121	1.5
Totals		*0*	*0*	*$—*	*0*	*$9,674*	*$(175)*	*$9,499*	*$8,740*	*0.9*

11.17 HVAC #14: Replace existing cooling systems with higher efficiency package units and chillers.

11.17.1 Existing conditions and problems

Some package units and chillers on site are old and inefficient, with COPs ranging from 2.1 to 3.4.

11.17.2 Current technology

Current technologies are old, inefficient electric packaged AC units and electric chillers.

11.17.3 Recommended solution

Replace older package units and chillers with new high efficiency package units and water cooled chillers, with COPs ranging from 3.1 to 5.2.

Replace existing electric package unit with more efficient system.

Replace existing electric chillers with more efficient chillers.

11.17.4 Energy savings

FEDS calculates an energy savings of 587 MMBtu/yr. This is $24,425/yr in savings.

11.17.5 Additional benefits

The maintenance cost savings is $1,086/yr for the new chillers and package units.

11.17.6 Investment

The new chillers and package units will cost $266,311, with installation.

11.17.7 Payback

Simple payback will occur in 10.4 yrs.

Table 33. Summary of HVAC#14a: Replace existing electric package unit with more efficient system.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
HVAC_14A	Replace existing with Single Zone Packaged AC Unit (very high efficiency / medium)	315	26	$11,754	11754	$–	$54	$11,808	$87,243	7.4
Totals		*315*	*26*	*$11,754*	*11754*	*$–*	*$54*	*$11,808*	*$87,243*	*7.4*

Table 34. Summary of HVAC#14b: Replace existing electric chillers with more efficient chillers.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
HVAC_14B	Replace Existing Chiller with Water–Cooled Centrifugal Electric Chiller (ultra high efficiency)	136	35	$6,249	6,249	$–	$1,035	$7,284	$103,410	14.2
HVAC_14C	Replace Existing Chiller with Water–Cooled Reciprocating Electric Chiller (high efficiency) and Cooling Tower	136	34	$6,422	6,422	$–	$(3)	$6,419	$75,658	11.8
Totals		*272*	*69*	*$12,671*	*12,671*	*$–*	*$1,032*	*$13,703*	*$179,068*	*13.1*

12 Summary, Conclusions, and Recommendations

12.1 Summary and conclusions

This work conducted an Energy Optimization Assessment at West Point military academy as a part of the IEA ECBCS initiative to identify energy inefficiencies and wastes and to propose energy-related projects with applicable funding and execution methods that could enable the installation to better meet the energy reduction requirements mandated by Executive Order 13123 and EPACT 2005.

A team of researchers from ERDC-CERL and PNNL and SMEs conducted the study, which was limited to the Level I assessment. The study included an analysis of building envelopes, ventilation air systems, controls, interior and exterior lighting as well as evaluation of opportunities to use renewable energy resources.

The study identified a total of 281 different potential ECMs, 275 of which were economically quantified, and which are summarized in Appendix A. These ECMs are organized into nine categories (summarized in Table 35):

1. Building Envelope
2. Central Energy Plant
3. Hot Water Heaters.
4. Renewables and Water
5. Controls
6. Dining Facilities
7. Electrical
8. Lighting
9. HVAC

If all these ECMs were implemented, they would result in approximate savings of $18.6 million/yr:

- 92,824 MWh/yr in electrical energy use savings
- reduction of electrical demand of 11,712 KW
- 427,230 MMBtu/yr in thermal savings (mostly natural gas)
- $1.1 million/yr in maintenance savings.

Implementation of these projects would require investment of $58.3 million and will yield an average simple payback of 3.1 yrs.

Table 35. Summary of nine Energy Conservation Measures (ECMs).

ECM Category	Report Chapter	Electrical Savings			Thermal MMBtu/yr	$/yr	Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr						
Building Envelope	3	4,299,124	4,697	$698,256	223,388	$2,917,246	$0	$3,615,502	$17,859,735	4.9
Central Energy Plant	4	56,841,394	4,695	7,162,741	89,287	813,368	518,879	8,494,988	33,727,949	4.0
Hot Water Heaters	11	2,054,135	246	$243,978	7,448	$107,520	−$291	$351,207	$326,495	0.9
Renewables & Water	10	−10,000	0	−$1,250	2,700	$33,453	$0	$67,993	$385,000	5.7
Controls	5	1,185,000	0	$148,125	21,726	$269,185	$0	$417,310	$315,500	0.8
Dining Facilities	6	137,000	0	$17,125	4,214	$52,211	$0	$69,336	$124,600	1.8
Lighting	9	10,589,479	1,979	$1,308,971	(17,476)	($241,324)	$522,560	$1,590,207	$3,368,892	2.1
Electrical	7	600,270	0	$75,034	0	$0	$0	$75,034	$3,150	0.0
HVAC	8	17,127,711	95	$2,144,516	95,943	$1,279,420	$10,646	$3,934,582	$2,205,394	0.6
Total		*92,824,112*	*11,712*	*$11,797,496*	*427,230*	*$5,231,080*	*$1,051,794*	*$18,616,159*	*$58,316,715*	*3.1*

Forty-three of these ECMs are a result of SME analyses, which included a survey of the particular building that each ECM applies to. The other 238 ECMs are a result of modeling the installation's energy use using the FEDS tool. Because the FEDS analysis does not involve a visit to each building an ECM is proposed for, the analysis is not as thorough as the SME ECMs.

Note that the FEDS ECMs were further divided into subsets of ECMs, which are fully described in Chapters 3 through 11 (indicated in the tables following each ECM group description). ECM summaries resulting from FEDS analysis are indicated by an asterisk in Tables 35 through 43.

The **Building Envelope** category consists of 72 ECMs (Table 36). BE #5 through BE #9 are summaries of ECMs for groups of buildings, which result from a FEDS analysis, and which can be broken into smaller projects as indicated in Sections 3.5 through 3.9. If all Building Envelope ECMs were implemented, they would save 4,299 MWh/yr; 4,697KW Demand; 223,388 MMBtu/yr in thermal savings resulting in a total savings of $3.6 million/yr. The investment cost of $17.9 million results in a simple payback of 4.9 yrs.

The **CEP** category consists of nine ECMs (Table 37). If all CEP ECMs were implemented, they would save 1,185 MWh/yr; 21,727 MMBtu/yr in thermal savings; for a total savings of $417K/yr. The investment cost of $316K results in a simple payback of 0.8 yrs.

Table 38 summarizes 38 **Hot Water Heater Insulation** ECMs identified by FEDS. Detailed descriptions can be found in Chapter 11. These could save 2,054 MWh/yr electrical use; reduce peak electrical demand by 246KW; and 7,448 MMBTU in thermal savings for a total savings of $351K/yr resulting in a simple payback of 0.9 yrs.

Table 39 summarizes one **Renewable** and one **Water** ECM. Shower water heat recovery would save 2,700 MMBTU/yr for a savings of $33K/yr. The investment cost of $245K results in a simple payback of 7.3 yrs. Fixing leaks in 15 cooling towers and installing a common condensing unit in Taylor Hall would save 19,000 million gallons of water/yr and save $35K/yr. The investment of $140K results in a payback of 4.1 yrs.

Table 36. Summary of building envelope ECMs.

ECM #	ECM Description	Electrical Savings			Thermal MMBtu/yr	$/yr	Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint ($/yr)	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr						
BE #1	Establish a Cool Roofs Strategy	831,800	0	$103,975	–1060	–13133	$–	$90,842	$–	0.0
BE #2	Add Insulated Panels Behind Single Pane Windows, Gillis Field House Building 633	0	0	$–	24	297	$–	$297	$700	2.4
BE #3	Install Interior Windows in Building 622 (Library) and In the Basement of Building 685	0	0	$–	0	0	$–	$–	$–	–
BE #4	Insulate Attic in Southern Part of Building 622	0	0	$–	376	4655	$–	$4,655	$50,500	10.8
BE_5*	Attic Ceiling: Increase Insulation by R–13 (blow–in cellulose)	4,689	103	$2,640	8053	104264	$–	$106,904	$470,233	4.4
BE 6*	Add Insulation to Interior Surface of Metal Roof: 4-in. Fiberglass	789,827	1,383	$140,716	45944	618225	$–	$758,941	$1,762,796	2.3
BE 7*	Insulate Roof	2,079,632	2,113	$336,224	92297	1166259	$–	$1,502,483	$3,494,383	2.3
BE 8*	Insulate Wall	118,694	189	$19,999	16300	221322	$–	$241,321	$2,995,075	12.4
BE 9*	Install Thermal Break or Double Pane Window	474,482	909	$94,702	61454	815357	$–	$910,059	$9,086,048	10.0
Totals		*4,299,124*	*4,697*	*698,256*	*223,388*	*2,917,246*	*0*	*3,615,502*	*17,859,735*	*4.9*

Table 37. Summary of central energy plant ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
CEP #1	Install Missing Insulation In CEP And Heat Distribution, Repair Leaks	0	0	$–	0	$–	$–	$–	$–	–
CEP #2	Gas Metering For Main CEP In Building 604	0	0	$–	40,000	$495,600	$–	$495,600	$69,384	0.1
CEP #3	Small Boiler In CEP Building 845 (Laundry Boiler)	0	0	$–	22,680	$281,005	$–	$281,005	$800,850	2.8
CEP #4	Reduce Steam Pressure To A Standardized Mid Or Low Pressure	0	0	$–	3,600	$44,604	$3,000	$47,604	$310,000	6.5
CEP #5	Longer Use Of The Backpressure Steam Turbine By Increasing The Low Pressure Steam Demand	1,200,000	0	$150,000	0	$–	$–	$150,000	$240,000	1.6
CEP #6	Interconnect The North And The Central Heating Distribution System	0	0	$–	22,680	$281,005	$–	$281,005	$200,000	0.7
CEP #7	Hot Water Conversion And Replacement Of The Unstable Tunnels	0	0	$–	7,200	$89,208	$240,000	$329,208	$700,000	2.1
CEP #8	Trigen Plant In CEP 604	55,957,440	5,000	$7,042,747	–296,000	$(3,667,440)	$–	$3,375,307	$28,200,000	8.4
CEP #9*	Abandon CEP 604 and install heating and hot water systems in buildings	–316,046	–305	$(30,006)	289,127	$3,289,386	$275,879	$3,535,259	$3,207,715	0.9
Totals		*56,841,394*	*4,695*	*$7,162,741*	*89,287*	*$813,368*	*$518,879*	*$8,494,988*	*$33,727,949*	*4.0*

Table 38. Summary of hot water ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MBtu/yr	$/yr				
SHW #1*	Replace existing water Heaters	1,033,369	107	$121,742	4308	$67,499	$(291)	$188,950	$209,693	1.1
SHW #2*	Wrap Hot Water Tank With Insulation	1,020,767	139	$122,236	3140	$40,021	0	$162,257	$116,802	0.7
Totals		*2,054,135*	*246*	*243,978*	*7,448*	*107,520*	*–291*	*351,207*	*326,495*	*0.9*

Table 39. Summary of renewable and water conservation ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
REN #1	Barracks Shower Hot Water Heat Recovery	0	0	$—	2700	$33,453	$—	$33,453	$245,000	7.3
WATER #1	Fix Cooling Tower Leaks	(10,000)	0	$(1,250)	0	$—	$—	$34,540	$140,000	4.1
Totals		*(10,000)*	*0*	*$(1,250)*	*2700*	*$33,453*	*$—*	*$67,993*	*$385,000*	*5.7*

The **Controls** category consists of nine ECMs (Table 40). If all Controls ECMs were implemented, they would save 1,185 MWh/yr; 21,726 MMBtu/yr in thermal savings resulting in a total savings of $417K/yr. The investment cost of $316K results in a simple payback of 0.8 yrs.

The **Dining** ECM group consists of three ECMs (Table 41). If all were implemented, they would save 600 MWh/yr resulting in savings of $75K/yr. The investment cost of $3,150 results in a simple payback of 1.8 yrs.

Table 42 summarizes the 103 **Lighting** ECMs. LI #5 through LI #10 are summaries of ECMs for groups of buildings, which resulted from a FEDS analysis, and which can be broken into smaller projects as indicated in Sections 9.5 through 9.10. If all were implemented, they would save 10.6 million MWh/yr; reduce peak electrical demand by 1,979 KW; have a 17,476 MMBtu/yr thermal penalty; and reduce maintenance costs by $523K/yr resulting in total savings of $1.6 million/yr. The investment cost of $3.4 million results in a simple payback of 2.1 yrs.

The **Electrical** ECM group consists of two ECMs (listed in Table 43). If implemented they would save 600 MWh/yr or $75K/yr. The investment cost of $3,150 results in a simple payback of 0.04 yrs.

Table 44 lists the 42 **HVAC** ECMs. HVAC #10 through HVAC #14 are summaries of ECMs for groups of buildings, which resulted from a FEDS analysis, and which can be broken into smaller projects as indicated in Sections 8.10 through 8.15. If all HVAC ECMs were implemented, they would save 17,128 MWh/yr; 95KW in electrical demand; 95,943 MMBtu/yr in thermal savings, and $11K in maintenance savings resulting in a total savings of $3.9 million/yr. The investment cost of $2.2 million results in a simple payback of 0.6 yrs.

The Level I analyses of multiple complex systems conducted during the Energy Optimization Assessment are not intended to be (nor should they be) precise. The quantity and quality of the systems improvements identified suggests that significant potential exists.

Table 40. Summary of controls ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
CON #1	Increase / Decrease Space Temperature Setpoints and Make Them Uniform	0	0	$–	0	$–	$–	$–	$–	–
CON #2	Reduce HVAC Run Time / Schedule AHUs To Match Building Occupancy	86,000	0	$10,750	1,233	$15,277	$–	$26,027	$20,000	0.8
CON #3	Improved Temperature Control in Kitchen, Building 745	25,500	0	$3,188	383	$4,745	$–	$7,933	$5,000	0.6
CON #4	Keller Army Hospital AHUs Retrofit And Controls	772,000	0	$96,500	16,800	$208,152	$–	$304,652	$200,000	0.7
CON #5	Control Motor VFDs Instead Of Full Constant Speed and Replace Malfunctioning VFDs	105,000	0	$13,125	0	$–	$–	$13,125	$5,000	0.4
CON #6	Remove Pneumatic Thermostats From Spaces With DDC Controls	6,500	0	$813	0	$–	$–	$813	$500	0.6
CON #7	Connect More Mechanical Equipment to EMCS	0	0	$–	0	$–	$–	$–	$–	–
CON #8	Initiate Night/Weekend and Summer/Winter Setpoint Changes	0	0	$–	0	$–	$–	$–	$–	–
CON #9	Fix Failed Controls in PX, Building 1204	190,000	0	$23,750	3,310	$41,011	$–	$64,761	$85,000	1.3
Totals		*1,185,000*	*0*	*$148,125*	*21,726*	*$269,185*	*$–*	*$417,310*	*$315,500*	*0.8*

Table 41. Summary of dining facility ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
DIN #1	Modify Kitchen Hoods with End Skirts, Bldg 745	95,200	0	$11,900	1,114	$13,802	$–	$25,702	$19,600	0.8
DIN #2	Repair Freezer Door Sears, Building 745	41,800	0	$5,225	0	$–	$–	$5,225	$20,000	3.8
DIN #3	Heat Recovery from Refrigeration Machines, Building 745	0	0	$–	3,100	$38,409	$–	$38,409	$85,000	2.2
Totals		*137,000*	*0*	*$17,125*	*4,214*	*$52,211*	$–	*$69,336*	*$124,600*	*1.8*

Table 42. Summary of lighting ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
LI #1	Use Occupancy Sensors to Shut off Lights, Buildings 663, 714 727 & Various Barracks	363,886	0	$45,486	0	$–	$–	$45,486	$48,900	1.1
LI #2	Shut Off Exterior Lights During Daytime	38,300	0	$4,788	0	$–	$–	$4,788	$1,000	0.2
LI #3	Shut off Interior Lights during Daytime in Areas that are Bright from Daylight	6,000	0	$750	0	$–	$–	$750	$1,000	1.3
LI #4	Replace Incandescent Lights With CFL (Buildings 685, 622, 714)	34,000	0	$4,250	0	$–	$–	$4,250	$2,000	0.5
LI #5*	Replace existing exit signs with electroluminescent exit signs	6,076,536	1,224	$742,468	–11470	$(163,336)	273776	$852,908	$433,588	0.5
LI #6*	Replace existing exit signs with electroluminescent exit signs	1,701,571	229	$205,340	–2828	$(37,828)	144814	$312,326	$430,802	1.4
LI #7*	Replace T8 lighting with Super T8 lighting	884,782	205	$115,221	–796	$(9,850)	24808	$130,179	$1,155,946	8.9
LI #8*	Replace MH with High Efficient Electronic ballast MH lighting	189,617	49	$24,936	–149	$(1,842)	9144	$32,238	$263,543	8.2
LI #9*	Replace T12 with Super T8 lighting	1,259,913	265	$161,229	–2209	$(28,171)	64728	$197,786	$994,250	5.0
LI #10*	Replace metal halide high–bay lighting with T5 lighting	34,875	7	$4,504	–24	$(297)	$5,290	$9,497	$37,863	4.0
Totals		*10,589,479*	*1,979*	*$1,308,971*	*–17,476*	*$(241,324)*	*$522,560*	*$1,590,207*	*$3,368,892*	*2.1*

Table 43. Summary of electrical ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Plant Energy Savings		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr	MMBtu/yr	$/yr				
EL #1	Use Energy Efficient Electric Motors; Buildings 750, 5102, 5440, 6901	17,350	0	$2,169	0	$–	0	$–	$–	$2,169	$3,150	1.5
EL #2	Switch off Computers When Not In Use	582,920	0	$72,865	0	$–	0	$–	$–	$72,865	$–	0.0
Totals		*600,270*	*0*	*$75,034*	*0*	*$–*	*0*	*$–*	*$–*	*$75,034*	*$3,150*	*0.04*

Table 44. Summary of HVAC ECMs.

ECM #	ECM Description	Electrical Savings			Thermal		Plant Energy Savings		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr	MMBtu/yr	$/yr				
HVAC #1	Glycol heat recovery change	0	0	$–	682	$8,450	$–	$–	$–	$8,450	$5,000	0.6
HVAC #2	Heat Recovery from Computer Room Air-conditioning	0	0	$–	2,047	$25,362	$–	$–	$–	$25,362	$50,000	2.0
HVAC #3A*	New Solutions for Re-heat Condenser Heat, Building 655	1,135,000	0	$141,875	2,867	$35,522	$–	$–	$–	$177,397	$323,000	1.8
HVAC #3B*	New Solutions for Re-heat Heat Exchanger, Building 655	1,128,200	0	$141,025	2,867	$35,522	$–	$–	$–	$176,547	$483,000	2.7
HVAC #3C*	New Solutions for Re-heat Bypass Cooling Coil, Building 655	1,135,000	0	$141,875	2,867	$35,522	$–	$–	$–	$177,397	$317,000	1.8
HVAC #4	Re-Commissioning Of HVAC Systems And Controls	15,750,000	0	$1,968,750	70,313	$871,172	$–	$–	$–	$2,839,922	$160,000	0.1
HVAC #5	Use Existing Steam Absorption Chiller And Supplement With Small Electric Chiller At Hospital	0	0	$–	0	$–	$–	$–	$–	$–	$(300,000)	-
HVAC #6	Switch Off Boilers in Holleder Center; Use Local Gas Burners to Regenerate Desiccant Wheel in De-humidifier	64,500	0	$8,063	900	$11,151	$–	$–	$–	$19,214	$10,000	0.5

ECM #	ECM Description	Electrical Savings			Thermal		Plant Energy Savings		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr	MMBtu/yr	$/yr				
HVAC #7	Use Waste Heat from Ice Makers / Use Condenser Heat in the Holleder Building to Pre–heat Outdoor Air	0	0	$–	0	$–	$–	$–	$–	$–	$–	–
HVAC #8	Do Not Replace AHUs at the Keller Army Hospital	0	0	$–	0	$–	$–	$–	$–	$500,000	$500,000	1.0
HVAC #9	Install CO_2 Controls In The Keller Army Hospital	56,000	0	$7,000	6,100	$75,579	$–	$–	$–	$82,579	$100,000	1.2
HVAC 10*	Replace Boiler With More Efficient One	293	0	$27	3,527	$94,948	$–	$–	$2,879	$97,854	$404,626	4.1
HVAC 11*	Install Infrared Heating	–6,448	0	$(687)	5,121	$100,491	$–	$–	$8,582	$108,386	$365,931	22.2
HVAC 12*	Replace Existing Furnace with Condensing LPG Furnace – 92% Efficient	–43,668	0	$(4,937)	3,625	$47,071	$–	$–	$(1,726)	$40,408	$311,786	7.7
HVAC 13*	Add Automatic Electric Damper to Existing Boilers	0	0	$–	761	$9,674	$–	$–	$(175)	$9,499	$8,740	0.9
HVAC 14*	Replace Cooling Equipment	172,033	95	$24,425	0	$–	$–	$–	$1,086	$25,511	$266,311	10.4
Totals		*17,127,711*	*95*	*$2,144,516*	*95,943*	*$1,279,420*	*$–*	*$–*	*$10,646*	*$3,934,582*	*$2,205,394*	*0.6*
*Assumes Option A												

12.2 Recommendations

Because potential ECMs found were numerous, they were grouped to emphasize recommended implementation approaches. The first approach involved ECMs that have very little or no additional investment such as the cool roof strategy, which simply requires a change in policy regarding allowed roofing materials. Projects that require small investments (defined here as investments of $10K or less) were grouped together. Recommissioning of HVAC systems was identified as a separate group because of its wide applicability and typically quick payback. Projects recommended because of their simple payback potential of less than 6 yrs were grouped into those having a modest investment of $10K to $200K and those requiring greater than $200k investment. Several projects require a more detailed Level II analysis, such as those involving the central energy plants. Finally, ECMs were sorted and filtered to show those with the largest impact on maintenance costs.

12.2.1 Policy Related and Low Cost Measures

The following measures require virtually no additional capital investment. These low cost/low-risk (so-called “slam dunk”) can be implemented quickly and should be funded internally as soon as possible. While the estimated cost of establishing installation wide setpoints is $100K, this could be implemented as part of the planned expansion of the installation wide building control system at virtually no additional cost:

- Use a Cool Roof strategy.
- Establish an installation-wide building temperature setpoint.

12.2.2 Low cost projects

The following tables summarize ECMs that require investments. Table 45 lists 56 ECMs found to have an investment of $10K or less and result in a simple payback of less than 6 yrs. All 56 ECMs could be implemented as a group for a total of $169K, save $332K/yr, and result in a simple payback of just under 6 months. West Point should seek internal funding for these projects.

12.2.3 Re-commissioning

Although re-commissioning of HVAC systems was not economically analyzed, an aggressive re-commissioning of HVAC systems is recommended because numerous opportunities that typically have a very short payback period were noted throughout the installation. Since this also requires that the systems be periodically checked and maintained to retain the savings, it is recommended that West Point pursue this through third party financing such as an ESPC.

12.2.4 Short payback and moderate investment projects

Table 46 lists 124 ECMs with a simple payback of less than 10 yrs, but which require moderate investments of between $10K and $200K. These ECMs together would have annual savings of $5.9 million at a cost of $2.5 million for a simple payback of 0.4 yrs. Due to their size and complexity, some may need to be developed further by an Energy Optimization Assessment Level II effort.

12.2.5 Short payback and significant investment projects

Table 47 lists 10 ECMs with a simple payback of less than 6 yrs, but also require significant investments of over $200K each. These ECMs would have annual savings of $6.6 million at a cost of $7.5 million for a simple payback of 1.1 yrs. Due to their size and complexity, most need to be developed further by an Energy Optimization Assessment Level II effort. It is recommended that West Point apply for funds from IMCOM's Utility Modernization program for these projects.

12.2.6 Level II analysis candidates

Some of the ripest opportunities for savings come from the moderate and high cost ECMs identified. These often require a combination of in-house and outside support.

It is recommended that West Point pursue Level II of this Energy Optimization Assessment for select central energy plant and HVAC ECMs:

- ECMs CEP #3, CEP #4 and CEP #5, CEP #6, CEP #7, CEP #8, CEP #9
- HVAC #3A through HVAC #3C.

CEP #3 involves the boiler in Bldg 845, which supplies the laundry facility and a few other buildings. Three possible solutions are described and a simple cost benefit analysis presented for one of the solutions. The Level II analysis is required to determine the optimum solution.

CEP #4 and CEP #5 involve the output of steam pressure of the CEP located in Bldg 604. One possibility is to standardize output at a lower steam pressure that can be used by all buildings served with the minimization of the need for pressure reducing valves. The optimal pressure has to be found in a more detailed study. It depends on the hydraulic situation and the demand of high and mid pressure steam in the buildings. Another possibility is to more fully use the two steam turbines for production of electricity. A more detailed study of the costs and savings is required to determine the best option and better understand the economics.

CEP #6 proposes the interconnection of the north and the central heating distribution systems. This would allow more fully loaded and therefore more efficient boiler operation. Further analysis is needed to analyze the complexities of interconnected boilers, distribution systems, and building loads.

CEP #7 requires a Level II analysis not as a means of decisionmaking, rather it is required as a new design. The distribution tunnel system is such that it is unsafe and must be replaced regardless of energy use. The analysis would produce a design for a hot water system to replace the steam currently distributed.

CEP #8 and CEP #9 are related and would affect many of CEP #1 through CEP #7. The idea is to install, in CEP 604, a new gas turbine and a waste heat boiler. This boiler will generate steam to drive the existing back pressure turbine #2 in winter. This first part of the suggested measure is also described in the ECSM proposal from NORESCO in April 2005.

Recommendations for the scope of the Level II study can be based on the Level I and demonstration project results. A specific Level II scope will be jointly developed by the CERL and West Point teams through review and discussion of results documented in this Level I report. The Level II report will include an analysis that “guesses at nothing – measures everything.” The results will be a set of demonstrated process and systems improve-

ments based on hard numbers. CERL and expert consultants will provide guidance and further assistance in identifying a specific Level II scope of work, respective roles, and the most expeditious implementation path. This will begin with a formal review of this (Level I) report, combined with a planning session to organize the Level II program.

12.2.7 Significant maintenance savings projects

Table 48 lists ECMs with the greatest maintenance savings. It is recommended that West Point review these projects along with its maintenance program to determine the suitability of these ECMs as projects and or modification of maintenance contracts.

Table 45. Summary ECMs requiring an investment < $10k and yielding a simple payback < 6 yrs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
BE #1	Establish a Cool Roofs Strategy	831,800	0	$103,975	−1,060	$(13,133)	$–	$90,842	$–	0.0
EL #2	Switch off Computers When Not In Use	582,920	0	$72,865	0	$–	$–	$72,865	$–	0.0
SHW_2C	Wrap Tank with Insulation	0	0	$–	14	$236	$–	$236	$16	0.1
LI #2	Shut Off Exterior Lights During Daytime	38,300	0	$4,788	0	$–	$–	$4,788	$1,000	0.2
SHW_2B	Install Faucet Aerators	8,792	3	$1,259	0	$–	$–	$1,259	$266	0.2
SHW_2A	Wrap Tank with Insulation, LFSHs	0	0	$–	106	$1,758	$–	$1,758	$448	0.3
LI_5I	Replace incandescent lights with CFL	143,605	32	$18,919	−86	$(1,069)	$5,122	$22,972	$7,267	0.3
LI_5A	Replace incandescent lights with CFL	3,224	1	$432	0	$–	$141	$573	$186	0.3
LI_5E	Replace incandescent lights with CFL	49,236	7	$5,980	−74	$(920)	$1,881	$6,941	$2,597	0.4
CON #5	Control Motor VFDs Instead Of Full Constant Speed and Replace Malfunctioning VFDs	105,000	0	$13,125	0	$–	$–	$13,125	$5,000	0.4
LI_5Z	Replace incandescent lights with CFL	12,895	3	$1,738	0	$–	$791	$2,529	$969	0.4
LI_5K	Replace incandescent lights with CFL	293	0	$57	0	$–	$22	$79	$31	0.4
LI_5AB	Replace incandescent lights with CFL	2,638	1	$354	−7	$(83)	$190	$461	$186	0.4
HVAC_13D	Add Automatic Electric Damper to Existing Boilers	0	0	$–	243	$3,014	$(26)	$2,988	$1,290	0.4
HVAC_13B	Add Automatic Electric Damper to Existing Boilers	0	0	$–	46	$569	$(5)	$564	$248	0.4
LI #4	Replace Incandescent Lights With CFL (Buildings 685, 622, 714)	34,000	0	$4,250	0	$–	$–	$4,250	$2,000	0.5
LI_5B	Replace incandescent lights with CFL	4,103	0	$474	0	$–	$175	$649	$340	0.5
LI_5AA	Replace incandescent lights with CFL	10,844	4	$1,469	−24	$(293)	$1,012	$2,188	$1,159	0.5
HVAC_13A	Add Automatic Electric Damper to Existing Boilers	0	0	$–	117	$1,449	$(15)	$1,434	$771	0.5
LI_5U	Replace incandescent lights with CFL	70,337	9	$8,211	−145	$(1,792)	$3,208	$9,627	$5,260	0.5
LI_5Y	Replace incandescent lights with CFL	4,982	1	$574	0	$–	$105	$679	$396	0.6
HVAC #1	Glycol heat recovery change	0	0	$–	682	$8,450	$–	$8,450	$5,000	0.6
CON #6	Remove Pneumatic Thermostats From Spaces With DDC Controls	6,500	0	$813	0	$–	$–	$813	$500	0.6
CON #3	Improved Temperature Control in Kitchen, Building 745	25,500	0	$3,188	383	$4,745	$–	$7,933	$5,000	0.6

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
HVAC_13F	Add Automatic Electric Damper to Existing Boilers	0	0	$–	4	$45	$(1)	$44	$31	0.7
LI_6R	Replace existing exit signs with electroluminescent exit signs	14,360	2	$1,737	–25	$(307)	$2,885	$4,315	$3,150	0.7
LI_6B	Replace existing exit signs with electroluminescent exit signs	35,169	1	$4,161	0	$–	$2,317	$6,478	$6,301	1.0
LI_6L	Replace existing exit signs with electroluminescent exit signs	4,689	1	$574	–7	$(82)	$290	$782	$788	1.0
LI_6M	Replace existing exit signs with electroluminescent exit signs	12,895	2	$1,557	–23	$(288)	$772	$2,041	$2,100	1.0
LI_6K	Replace existing exit signs with electroluminescent exit signs	31,066	4	$3,790	–30	$(378)	$2,124	$5,536	$5,776	1.0
LI_6N	Replace existing exit signs with electroluminescent exit signs	4,103	0	$490	–3	$(39)	$290	$741	$788	1.1
LI_6O	Replace existing exit signs with electroluminescent exit signs	55,390	6	$6,664	–77	$(1,405)	$3,476	$8,735	$9,451	1.1
HVAC_13C	Add Automatic Electric Damper to Existing Boilers	0	0	$–	229	$2,840	$(62)	$2,778	$3,095	1.1
LI_6C	Replace existing exit signs with electroluminescent exit signs	16,705	2	$1,986	–33	$(405)	$1,159	$2,740	$3,150	1.1
LI_6D	Replace existing exit signs with electroluminescent exit signs	16,705	2	$1,986	–33	$(405)	$1,159	$2,740	$3,150	1.1
SHW_1H	Replace existing water heaters with Condensing LPG Boiler – 91% Combustion Efficiency, Wrap Tank, Aerators	0	0	$–	190	$3,488	$3	$3,491	$4,099	1.2
LI #3	Shut off Interior Lights during Daytime in Areas that are Bright from Daylight	6,000	0	$750	0	$–	$–	$750	$1,000	1.3
LI_5F	Replace incandescent lights with CFL	38,392	17	$4,675	0	$–	$1,838	$6,513	$8,904	1.4
EL #1	Use Energy Efficient Electric Motors; Buildings 750, 5102, 5440, 6901	17,350	0	$2,169	0	$–	$–	$2,169	$3,150	1.5
HVAC_13G	Add Automatic Electric Damper to Existing Boilers	0	0	$–	41	$758	$(22)	$736	$1,121	1.5
LI_5L	Replace incandescent lights with CFL	586	0	$81	0	$–	$35	$116	$186	1.6
LI_5D	Replace incandescent lights with CFL	7,913	4	$974	0	$–	$279	$1,253	$2,087	1.7
SHW_1E	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank, Aerators	0	0	$–	147	$4,259	$(62)	$4,197	$7,526	1.8
LI_6W	Replace existing exit signs with electroluminescent exit signs	3,224	0	$382	0	$–	$481	$863	$1,575	1.8
LI_6V	Replace existing exit signs with electroluminescent exit signs	9,085	1	$1,090	–12	$(146)	$1,444	$2,388	$4,725	2.0
LI_6X	Replace existing exit signs with electroluminescent exit signs	7,913	1	$950	–19	$(233)	$1,444	$2,161	$4,725	2.2
HVAC_10I	Replace Existing Boiler with Conventional Gas Boiler – 84% Combustion Efficiency	0	0	$–	40	$2,373	$29	$2,402	$5,258	2.2
HVAC_13E	Add Automatic Electric Damper to Existing Boilers	0	0	$–	81	$999	$(44)	$955	$2,184	2.3

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
BE #2	Add Insulated Panels Behind Single Pane Windows, Gillis Field House Building 633	0	0	$—	24	$297	$—	$297	$700	2.4
LI_5X	Replace incandescent lights with CFL	4,689	1	$575	0	$—	$184	$759	$2,640	3.5
BE_5C	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–1,172	2	$(76)	83	$1,029	$—	$953	$4,295	4.5
BE_5B	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–293	2	$(19)	150	$1,855	$—	$1,836	$9,192	5.0
LI_9G	Replace T12 with Super T8 lighting	9,085	2	$1,077	–17	$(216)	$465	$1,326	$7,365	5.6
LI_9F	Replace T12 with Super T8 lighting	10,844	2	$1,280	–22	$(269)	$548	$1,559	$8,679	5.6
LI_9J	Replace T12 with Super T8 lighting	3,810	0	$432	–7	$(87)	$165	$510	$2,865	5.6
HVAC_10F	Replace Existing Boiler with Conventional Gas Boiler – 84% Combustion Efficiency	0	0	$—	106	$1,313	$268	$1,581	$9,190	5.8
Totals		*2,243,477*	*113*	*$279,754*	*982*	*$17,927*	*$34,065*	*$331,747*	*$169,176*	*0.5*

Table 46. Summary of ECMs requiring investments between $10k and $200k and yielding a simple payback of less than 10 yrs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
HVAC #4	Re-Commissioning Of HVAC Systems And Controls	15,750,000	0	1,968,750	70,313	871,172	$–	$2,839,922	$160,000	$0.1
CEP #2	Gas Metering For Main CEP In Building 604	0	0	0	40,000	495,600	$–	$495,600	$69,384	$0.1
LI_5W	Replace incandescent lights with CFL	1,463,011	334	179,577	−2,261	−41,420	$66,393	$204,550	$75,935	$0.4
LI_5G	Replace incandescent lights with CFL	526,356	100	67,184	−995	−15,197	$22,711	$74,698	$28,602	$0.4
HVAC #6	Switch Off Boilers in Holleder Center; Use Local Gas Burners to Regenerate Desiccant Wheel in De-humidifier	64,500	0	8,063	900	11,151	$–	$19,214	$10,000	$0.5
LI_5P	Replace incandescent lights with CFL	530,459	71	62,315	−1,000	−12,388	$24,527	$74,454	$40,562	$0.5
LI_5M	Replace incandescent lights with CFL	204,564	35	23,899	−428	−5,306	$9,307	$27,900	$15,259	$0.5
LI_5T	Replace incandescent lights with CFL	525,769	91	61,778	−1,132	−14,031	$24,107	$71,854	$39,867	$0.6
LI_5Q	Replace incandescent lights with CFL	208,960	36	24,551	−447	−5,537	$9,634	$28,648	$15,932	$0.6
LI_5R	Replace incandescent lights with CFL	174,963	33	20,567	−360	−4,458	$8,175	$24,284	$13,520	$0.6
LI_5N	Replace incandescent lights with CFL	663,513	121	80,834	−1,707	−21,669	$30,713	$89,878	$50,355	$0.6
LI_5C	Replace incandescent lights with CFL	135,106	19	16,339	−268	−3,326	$5,335	$18,348	$10,358	$0.6
LI_5J	Replace incandescent lights with CFL	393,008	114	53,864	−643	−7,971	$16,713	$62,606	$36,565	$0.6
LI_5S	Replace incandescent lights with CFL	181,997	32	21,392	−424	−6,423	$8,342	$23,311	$13,677	$0.6
SHW_1D	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank	0	0	0	2,778	34,416	$133	$34,549	$20,278	$0.6
LI_5V	Replace incandescent lights with CFL	369,856	67	43,550	−897	−12,595	$17,155	$48,110	$28,371	$0.6
LI_5O	Replace incandescent lights with CFL	232,698	41	27,318	−572	−8,858	$10,743	$29,203	$17,767	$0.6
CON #4	Keller Army Hospital AHUs Retrofit And Controls	772,000	0	96,500	16,800	208,152	$–	$304,652	$200,000	$0.7
CEP #6	Interconnect The North And The Central Heating Distribution System	0	0	0	22,680	281,005	$–	$281,005	$200,000	$0.7
LI_6S	Replace existing exit signs with electroluminescent exit signs	66,527	8	7,920	0	0	$15,387	$23,307	$16,802	$0.7
LI_5H	Replace incandescent lights with CFL	112,539	50	14,787	0	0	$4,938	$19,725	$14,610	$0.7

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
SHW_1A	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank	463,932	55	55,531	−1,297	−16,074	$(249)	$39,208	$29,359	$0.7
DIN #1	Modify Kitchen Hoods with End Skirts, Bldg 745	95,200	0	11,900	1,114	13,802	$–	$25,702	$19,600	$0.8
CON #2	Reduce HVAC Run Time / Schedule AHUs To Match Building Occupancy	86,000	0	10,750	1,233	15,277	$–	$26,027	$20,000	$0.8
SHW_1C	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank	0	0	0	1,838	22,771	$(14)	$22,757	$18,042	$0.8
BE_6Q	Suspended Ceiling: Increase Insulation by R–19	220,096	269	36,446	9,020	111,764	$–	$148,210	$137,712	$0.9
SHW_1I	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank, LFSHs, Aerators	251,455	30	29,989	−731	−9,052	$(143)	$20,794	$20,163	$1.0
LI_6A	Replace existing exit signs with electroluminescent exit signs	212,477	24	25,320	0	0	$14,772	$40,092	$40,166	$1.0
SHW_1L	Replace existing water heaters with Conventional Distillate Oil Boiler – 86.5% Combustion Efficiency, Wrap Tank, Aerators	0	0	0	1,164	24,970	$335	$25,305	$25,936	$1.0
LI_6J	Replace existing exit signs with electroluminescent exit signs	115,470	13	13,736	−44	−539	$8,014	$21,211	$21,790	$1.0
LI #1	Use Occupancy Sensors to Shut off Lights, Buildings 663, 714 727 & Various Barracks	363,886	0	45,486	0	0	$–	$45,486	$48,900	$1.1
LI_6G	Replace existing exit signs with electroluminescent exit signs	123,969	19	15,112	−255	−3,156	$7,820	$19,776	$21,264	$1.1
LI_6I	Replace existing exit signs with electroluminescent exit signs	176,136	27	21,428	−426	−5,980	$11,007	$26,455	$29,928	$1.1
LI_6E	Replace existing exit signs with electroluminescent exit signs	361,357	56	43,999	−939	−11,917	$22,882	$54,964	$62,218	$1.1
LI_6H	Replace existing exit signs with electroluminescent exit signs	110,781	17	13,503	−264	−3,989	$6,952	$16,466	$18,902	$1.1
LI_6F	Replace existing exit signs with electroluminescent exit signs	65,062	9	7,875	−161	−2,484	$4,055	$9,446	$11,026	$1.2
LI_6Q	Replace existing exit signs with electroluminescent exit signs	58,321	7	6,950	−135	−1,672	$4,055	$9,333	$11,026	$1.2
LI_6P	Replace existing exit signs with electroluminescent exit signs	66,820	8	7,944	−166	−2,057	$4,634	$10,521	$12,601	$1.2
HVAC #9	Install CO_2 Controls In The Keller Army Hospital	56,000	0	7,000	6,100	75,579	$–	$82,579	$100,000	$1.2
CON #9	Fix Failed Controls in PX, Building 1204	190,000	0	23,750	3,310	41,011	$–	$64,761	$85,000	$1.3
BE_6G	Attic Ceiling: Increase Insulation by R–30 (blow–in cellulose)	0	0	0	1,715	31,407	$–	$31,407	$51,508	$1.6
BE_6H	Attic Ceiling: Increase Insulation by R–30 (blow–in cellulose)	0	0	0	3,359	51,287	$–	$51,287	$85,322	$1.7
BE_6U	Suspended Ceiling: Increase Insulation by R–38	14,947	48	4,545	1,511	18,724	$–	$23,269	$39,202	$1.7

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
SHW_1G	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank, LFSHs	0	0	0	530	6,569	$(101)	$6,468	$10,965	$1.7
SHW_1F	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank, LFSHs	164,413	0	17,424	–439	–5,434	$(116)	$11,874	$20,220	$1.7
BE_6L	Attic Ceiling: Increase Insulation by R–38 (blow–in cellulose)	55,390	58	9,088	2,334	35,326	$–	$44,414	$77,715	$1.7
BE_6D	Attic Ceiling: Increase Insulation by R–30 (blow–in cellulose)	26,963	39	5,314	1,965	24,349	$–	$29,663	$54,199	$1.8
BE_6M	Attic Ceiling: Increase Insulation by R–38 (blow–in cellulose)	131,003	138	21,628	5,578	78,361	$–	$99,989	$182,706	$1.8
BE_6E	Attic Ceiling: Increase Insulation by R–30 (blow–in cellulose)	36,341	66	7,389	2,707	33,544	$–	$40,933	$75,455	$1.8
LI_6U	Replace existing exit signs with electroluminescent exit signs	80,595	12	9,785	–93	–1,234	$11,550	$20,101	$37,804	$1.9
HVAC #2	Heat Recovery from Computer Room Air–conditioning	0	0	0	2,047	25,362	$–	$25,362	$50,000	$2.0
LI_6T	Replace existing exit signs with electroluminescent exit signs	31,945	5	3,862	–55	–782	$4,813	$7,893	$15,751	$2.0
BE_6W	Suspended Ceiling: Increase Insulation by R–38	–15,826	251	12,809	4,708	62,606	$–	$75,415	$155,278	$2.1
BE_6F	Attic Ceiling: Increase Insulation by R–30 (blow–in cellulose)	0	0	0	1,503	24,996	$–	$24,996	$52,436	$2.1
DIN #3	Heat Recovery from Refrigeration Machines, Building 745	0	0	0	3,100	38,409	$–	$38,409	$85,000	$2.2
HVAC_11E	Replace Existing Boiler with Natural Gas Infrared Heating System – High Efficiency	–1,758	0	–189	314	7,275	$413	$7,499	$16,606	$2.2
HVAC_11F	Replace Existing Boiler with Natural Gas Infrared Heating System – Medium Efficiency	0	0	0	1,015	21,521	$4,290	$25,811	$57,832	$2.2
HVAC_10J	Replace Existing Boiler with Conventional Gas Boiler – 84% Combustion Efficiency	0	0	0	86	5,568	$251	$5,819	$13,326	$2.3
SHW_1K	Replace existing water heaters with Conventional Gas Boiler – 84% Combustion Efficiency, Wrap Tank	153,569	22	18,798	–498	–6,166	$63	$12,695	$29,961	$2.4
HVAC_10G	Replace Existing Boiler with Conventional Gas Boiler – 84% Combustion Efficiency	0	0	0	209	13,527	$402	$13,929	$33,628	$2.4
LI_9B	Replace T12 with Super T8 lighting	511,116	72	61,718	–1,180	–14,620	$13,355	$60,453	$149,602	$2.5
HVAC_10C	Replace Existing Boiler with Condensing Gas Boiler – 91% Combustion Efficiency	293	0	27	578	29,003	$(998)	$28,032	$70,449	$2.5
SHW_1J	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank, LFSHs, Aerators	0	0	0	587	7,272	$(112)	$7,160	$19,505	$2.7
BE_6P	Suspended Ceiling: Increase Insulation by R–19	0	0	0	1,653	20,480	$–	$20,480	$60,029	$2.9
BE_6T	Suspended Ceiling: Increase Insulation by R–38	6,741	27	1,502	1,388	17,194	$–	$18,696	$56,294	$3.0

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
BE_5O	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	0	0	0	1,307	19,946	$–	$19,946	$60,310	$3.0
HVAC_10H	Replace Existing Boiler with Conventional Gas Boiler – 84% Combustion Efficiency	0	0	0	95	9,686	$590	$10,276	$32,190	$3.1
HVAC_11A	Replace Existing Boiler with LPG Infrared Heating System – High Efficiency	0	0	0	2,209	40,467	$3,181	$43,648	$142,828	$3.3
BE_6V	Suspended Ceiling: Increase Insulation by R–38	35,755	90	7,916	3,221	39,910	$–	$47,826	$158,134	$3.3
LI_10A	Replace metal halide high–bay lighting with T5 lighting	15,826	4	2,133	0	0	$4,136	$6,269	$21,429	$3.4
BE_6O	Suspended Ceiling: Increase Insulation by R–19	2,345	0	259	480	5,951	$–	$6,210	$21,544	$3.5
BE_5L	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–1,758	49	1,218	3,722	46,121	$–	$47,339	$168,659	$3.6
BE_5K	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–2,051	8	41	559	6,921	$–	$6,962	$25,880	$3.7
DIN #2	Repair Freezer Door Sears, Building 745	41,800	0	5,225	0	0	$–	$5,225	$20,000	$3.8
LI_7B	Replace T8 lighting with Super T8 lighting	134,227	38	18,277	–146	–1,804	$3,428	$19,901	$78,108	$3.9
WATER #1	Fix Cooling Tower Leaks	–10,000	0	–1,250	0	0	$–	$34,540	$140,000	$4.1
BE_6N	Suspended Ceiling: Increase Insulation by R–11	188,445	292	18,798	0	0	$–	$18,798	$77,053	$4.1
BE_5F	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–11,137	18	–740	807	10,742	$–	$10,002	$41,725	$4.2
HVAC_11B	Replace Existing Furnace with LPG Infrared Heating System – High Efficiency	0	0	0	1,163	21,310	$1,141	$22,451	$104,383	$4.6
HVAC_11D	Replace Existing Steam FCU with Natural Gas Infrared Heating System – High Efficiency	–3,224	0	–346	295	6,957	$(311)	$6,300	$31,059	$4.9
HVAC_11C	Replace Existing Steam AHU with Natural Gas Infrared Heating System – High Efficiency	–1,465	0	–152	125	2,961	$(132)	$2,677	$13,223	$4.9
LI_10B	Replace metal halide high–bay lighting with T5 lighting	19,050	3	2,371	–24	–297	$1,154	$3,228	$16,434	$5.1
BE_6J	Attic Ceiling: Increase Insulation by R–30 (blow–in cellulose)	24,325	20	3,737	672	8,323	$–	$12,060	$64,029	$5.3
BE_6K	Attic Ceiling: Increase Insulation by R–30 (blow–in cellulose)	34,582	50	6,233	2,348	29,086	$–	$35,319	$188,815	$5.3
LI_7A	Replace T8 lighting with Super T8 lighting	50,115	14	6,877	–37	–461	$842	$7,258	$39,565	$5.5
LI_9E	Replace T12 with Super T8 lighting	27,842	4	3,259	–49	–602	$1,395	$4,052	$22,096	$5.5
LI_9I	Replace T12 with Super T8 lighting	27,549	5	3,244	–55	–681	$1,371	$3,934	$21,717	$5.5
HVAC_10K	Replace Existing Boiler with Conventional LPG Boiler – 84% Combustion Efficiency	0	0	0	605	11,079	$884	$11,963	$66,056	$5.5
BE_6I	Attic Ceiling: Increase Insulation by R–30 (blow–in cellulose)	4,396	9	962	406	5,032	$–	$5,994	$33,465	$5.6

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
LI_9A	Replace T12 with Super T8 lighting	143,312	41	19,532	–297	–3,682	$4,616	$20,466	$114,564	$5.6
HVAC_10B	Replace Existing Boiler with Condensing Gas Boiler – 91% Combustion Efficiency	0	0	0	708	8,766	$(257)	$8,509	$49,286	$5.8
LI_9K	Replace T12 with Super T8 lighting	19,343	3	2,283	–43	–614	$976	$2,645	$15,455	$5.8
LI_9C	Replace T12 with Super T8 lighting	34,875	6	4,157	–83	–1,055	$1,583	$4,685	$27,430	$5.9
LI_6AK	Replace existing exit signs with electroluminescent exit signs	5,861	1	717	–5	–58	$2,834	$3,493	$22,052	$6.3
BE_5G	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	0	0	0	143	1,771	$–	$1,771	$11,193	$6.3
LI_6AD	Replace existing exit signs with electroluminescent exit signs	3,224	0	397	–6	–77	$1,619	$1,939	$12,601	$6.5
LI_6AF	Replace existing exit signs with electroluminescent exit signs	2,638	0	310	–2	–24	$1,518	$1,804	$11,814	$6.5
LI_6AA	Replace existing exit signs with electroluminescent exit signs	3,224	1	401	–5	–64	$1,822	$2,159	$14,176	$6.6
BE_6S	Suspended Ceiling: Increase Insulation by R–19	2,051	2	685	480	8,789	$–	$9,474	$64,222	$6.8
BE_5E	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–2,345	5	–163	281	3,478	$–	$3,315	$22,536	$6.8
BE_5J	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	0	0	0	155	1,926	$–	$1,926	$13,099	$6.8
HVAC_12A	Replace Existing Furnace with Condensing Gas Furnace – 92% Efficient	2,638	0	312	2,151	26,654	$(949)	$26,017	$177,576	$6.8
HVAC_10A	Replace Existing Boiler with Condensing Gas Boiler – 91% Combustion Efficiency	0	0	0	718	8,901	$(132)	$8,769	$60,457	$6.9
LI_7F	Replace T8 lighting with Super T8 lighting	58,321	6	6,946	0	0	$15	$6,961	$49,017	$7.0
HVAC_14A	Replace existing with Single Zone Packaged AC Unit (very high efficiency / medium)	92,317	26	11,754	0	0	$54	$11,808	$87,243	$7.4
BE_5H	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–2,638	4	–187	212	2,622	$–	$2,435	$18,204	$7.5
HVAC_10E	Replace Existing Boiler with Conventional Gas Boiler – 84% Combustion Efficiency	0	0	0	176	2,178	$27	$2,205	$16,485	$7.5
BE_9E	Install Thermal Break Aluminum Frame Double Pane Argon/Low–e Window	0	0	0	940	17,223	$–	$17,223	$134,378	$7.8
LI_8A	Replace MH with Biaxial Florescent lighting	109,609	31	14,963	–100	–1,236	$4,701	$18,428	$145,713	$7.9
BE_7B	Add Insulation to Interior Surface of Metal Roof: 4–in. Fiberglass	19,050	48	4,729	1,275	18,075	$–	$22,804	$189,117	$8.3
LI_8B	Replace MH with Biaxial Florescent lighting	50,701	12	6,344	–32	–391	$2,541	$8,494	$70,963	$8.4
LI_8C	Replace MH with Biaxial Florescent lighting	27,842	6	3,472	–17	–215	$1,391	$4,648	$38,846	$8.4
BE_9B	Install Thermal Break Aluminum Frame Double Pane Argon/Low–e Window	–7,913	5	–717	1,074	13,302	$–	$12,585	$107,073	$8.5

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
BE_6R	Suspended Ceiling: Increase Insulation by R–19	1,172	4	294	265	3,287	$–	$3,581	$30,623	$8.6
LI_7G	Replace T8 lighting with Super T8 lighting	60,959	9	7,588	–56	–694	$1,259	$8,153	$69,964	$8.6
BE_5M	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	7,620	5	951	390	4,830	$–	$5,781	$49,882	$8.6
BE_6B	Attic Ceiling: Increase Insulation by R–13 (blow–in cellulose)	18,170	13	2,519	519	6,426	$–	$8,945	$78,086	$8.7
HVAC_12C	Replace Existing Furnace with Condensing LPG Furnace – 92% Efficient	–11,430	0	–1,314	340	6,086	$(255)	$4,517	$40,349	$8.9
BE_5A	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	16,705	6	1,439	0	0	$–	$1,439	$12,967	$9.0
BE_9D	Install Thermal Break Aluminum Frame Double Pane Argon/Low–e Window	0	0	0	529	8,791	$–	$8,791	$80,471	$9.2
HVAC_12B	Replace Existing Furnace with Condensing Gas Furnace – 92% Efficient	–33,410	0	–3,776	1,086	13,458	$(484)	$9,198	$87,865	$9.6
BE_6C	Attic Ceiling: Increase Insulation by R–19 (blow–in cellulose)	879	4	266	112	1,383	$–	$1,649	$15,760	$9.6
LI_7K	Replace T8 lighting with Super T8 lighting	83,818	23	11,368	–93	–1,148	$1,053	$11,273	$109,659	$9.7
BE_8E	Blow–in Wall Insulation to Fill Available Space	0	0	0	541	9,908	$–	$9,908	$98,217	$9.9
Totals		*25,934,382*	*2,052*	*$3,234,941*	*182,857*	*$2,288,051*	*$374,579*	*$5,897,571*	*$2,512,324*	*0.4*

Table 47. Summary of ECMs requiring an investment > $200k and yielding a simple payback < 6 yrs.

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
BE_7A	Add Insulation to Interior Surface of Metal Roof: 4 ––in. Fiberglass	6,620	1,986	$313,768	$67,392	$855,393	$–	$1,169,161	$585,439	0.5
CEP #9_A	Abandon CEP 604 and install heating and hot water systems in buildings	–1,078	–305	$(30,006)	$289,127	$3,289,386	$275,879	$3,535,259	$3,207,715	0.9
HVAC #8	Do Not Replace AHUs at the Keller Army Hospital	0	0	$–	$–	$–	$–	$500,000	$500,000	1.0
CEP #5	Longer Use Of The Backpressure Steam Turbine By Increasing The Low Pressure Steam Demand	4,094	0	$150,000	$–	$–	$–	$150,000	$240,000	1.6

ECM #	ECM Description	Electrical Savings KWh/yr	kW Demand	$/yr	Thermal MMBtu/yr	$/yr	Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
HVAC #3C	New Solutions for Re–heat Bypass Cooling Coil, Building 655	3,873	0	$141,875	$2,867	$35,522	$–	$177,397	$317,000	1.8
HVAC #3A	New Solutions for Re–heat Condenser Heat, Building 655	3,873	0	$141,875	$2,867	$35,522	$–	$177,397	$323,000	1.8
CEP #7	Hot Water Conversion And Replacement Of The Unstable Tunnels	0	0	$–	$7,200	$89,208	$240,000	$329,208	$700,000	2.1
HVAC #3B	New Solutions for Re–heat Heat Exchanger, Building 655	3,849	0	$141,025	$2,867	$35,522	$–	$176,547	$483,000	2.7
CEP #3	Small Boiler In CEP Building 845 (Laundry Boiler)	0	0	$–	$22,680	$281,005	$–	$281,005	$800,850	2.8
LI_9L	Replace T12 with Super T8 lighting	1,443	123	$58,276	$(368)	$(4,891)	$21,417	$74,802	$372,718	5.0
Totals		*22,673*	*1,804*	*916,813*	*394,632*	*4,616,667*	*537,296*	*6,570,777*	*7,529,722*	*1.1*

Table 48. Summary of ECMs with greatest maintenance savings.

ECM #	ECM Description	Electrical Savings KWh/yr	kW Demand	$/yr	Thermal MMBtu/yr	$/yr	Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
LI_5I	Replace incandescent lights with CFL	490	32	$18,919	$(86)	$(1,069)	$5,122	$22,972	$7,267	0.3
LI_5C	Replace incandescent lights with CFL	461	19	$16,339	$(268)	$(3,326)	$5,335	$18,348	$10,358	0.6
LI_6H	Replace existing exit signs with electroluminescent exit signs	378	17	$13,503	$(264)	$(3,989)	$6,952	$16,466	$18,902	1.1
LI_7J	Replace T8 lighting with Super T8 lighting	510	26	$18,430	$–	$–	$7,682	$26,112	$254,576	9.7
LI_6G	Replace existing exit signs with electroluminescent exit signs	423	19	$15,112	$(255)	$(3,156)	$7,820	$19,776	$21,264	1.1
LI_6J	Replace existing exit signs with electroluminescent exit signs	394	13	$13,736	$(44)	$(539)	$8,014	$21,211	$21,790	1.0
LI_5R	Replace incandescent lights with CFL	597	33	$20,567	$(360)	$(4,458)	$8,175	$24,284	$13,520	0.6
LI_5S	Replace incandescent lights with CFL	621	32	$21,392	$(424)	$(6,423)	$8,342	$23,311	$13,677	0.6
LI_9N	Replace T12 with Super T8 lighting	54	2	$1,956	$(26)	$(479)	$8,919	$10,396	$118,006	11.4
LI_9M	Replace T12 with Super T8 lighting	55	2	$1,991	$(23)	$(377)	$9,079	$10,693	$120,131	11.2
LI_5M	Replace incandescent lights with CFL	698	35	$23,899	$(428)	$(5,306)	$9,307	$27,900	$15,259	0.5
LI_5Q	Replace incandescent lights with CFL	713	36	$24,551	$(447)	$(5,537)	$9,634	$28,648	$15,932	0.6

ECM #	ECM Description	Electrical Savings			Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		KWh/yr	kW Demand	$/yr	MMBtu/yr	$/yr				
LI_5O	Replace incandescent lights with CFL	794	41	$27,318	$(572)	$(8,858)	$10,743	$29,203	$17,767	0.6
LI_6I	Replace existing exit signs with electroluminescent exit signs	601	27	$21,428	$(426)	$(5,980)	$11,007	$26,455	$29,928	1.1
LI_6U	Replace existing exit signs with electroluminescent exit signs	275	12	$9,785	$(93)	$(1,234)	$11,550	$20,101	$37,804	1.9
LI_9B	Replace T12 with Super T8 lighting	1,744	72	$61,718	$(1,180)	$(14,620)	$13,355	$60,453	$149,602	2.5
LI_6A	Replace existing exit signs with electroluminescent exit signs	725	24	$25,320	$—	$—	$14,772	$40,092	$40,166	1.0
LI_6S	Replace existing exit signs with electroluminescent exit signs	227	8	$7,920	$—	$—	$15,387	$23,307	$16,802	0.7
LI_5J	Replace incandescent lights with CFL	1,341	114	$53,864	$(643)	$(7,971)	$16,713	$62,606	$36,565	0.6
LI_5V	Replace incandescent lights with CFL	1,262	67	$43,550	$(897)	$(12,595)	$17,155	$48,110	$28,371	0.6
LI_9L	Replace T12 with Super T8 lighting	1,443	123	$58,276	$(368)	$(4,891)	$21,417	$74,802	$372,718	5.0
LI_5G	Replace incandescent lights with CFL	1,796	100	$67,184	$(995)	$(15,197)	$22,711	$74,698	$28,602	0.4
LI_6E	Replace existing exit signs with electroluminescent exit signs	1,233	56	$43,999	$(939)	$(11,917)	$22,882	$54,964	$62,218	1.1
LI_5T	Replace incandescent lights with CFL	1,794	91	$61,778	$(1,132)	$(14,031)	$24,107	$71,854	$39,867	0.6
LI_5P	Replace incandescent lights with CFL	1,810	71	$62,315	$(1,000)	$(12,388)	$24,527	$74,454	$40,562	0.5
LI_5N	Replace incandescent lights with CFL	2,264	121	$80,834	$(1,707)	$(21,669)	$30,713	$89,878	$50,355	0.6
LI_5W	Replace incandescent lights with CFL	4,992	334	$179,577	$(2,261)	$(41,420)	$66,393	$204,550	$75,935	0.4
CEP #7	Hot Water Conversion And Replacement Of The Unstable Tunnels	0	0	$—	$7,200	$89,208	$240,000	$329,208	$700,000	2.1
CEP #9_A	Abandon CEP 604 and install heating and hot water systems in buildings	–1,078	–305	$(30,006)	$289,127	$3,289,386	$275,879	$3,535,259	$3,207,715	0.9
Totals		*26,616*	*1,222*	*965,255*	*$281,489*	*$3,171,164*	*$933,692*	*$5,070,111*	*$5,565,659*	*1.1*

12.3 Lessons learned

An Energy and Process Optimization Assessment (EPOA) is a complex undertaking. There are several key elements that require significant attention to guarantee success:

1. The involvement of key facility personnel who know what the problems are, where they are, and have thought of many solutions.
2. The facility personnel's sense of "ownership" of the ideas, which in turn develops a commitment for implementation.
3. The EPOA focus on site-specific, critical cost issues, which, if solved, will make the greatest possible economic contribution to the installation's facility's bottom-line.

Major cost issues are:

- facility use (bottlenecks)
- maintenance and repair optimization (off spec, scrap, rework)
- labor (productivity, planning/scheduling)
- energy (steam, electricity, compressed air)
- waste (air, water, solid, hazardous)
- equipment (outdated or state-of-the-art), etc.

From a cost perspective, facility capacity, materials, and labor use are far more significant than energy and environmental concerns. However, all of these issues must be considered together to achieve DOD's mission of military readiness in the most efficient, cost-effective way. The Energy Assessment Protocol developed by CERL in collaboration with a number of government, institutional, and private sector parties is based on the analysis of the information available from literature, training materials, documented and undocumented practical experiences of contributors, and successful showcase energy assessments conducted by a diverse team of experts at the U.S. Army facilities. The protocol addresses both technical and nontechnical, organizational capabilities required to conduct a successful assessment geared to identifying measures that can reduce energy and other operating costs without adversely impacting product quality, safety, morale, or the environment.

Expertise in energy auditing is not an isolated set of skills, methods, or procedures; it requires a combination of skills and procedures from different fields. However, an energy and process audit requires a specific talent

for putting together existing ways and procedures to show the overall energy performance of a building and the processes it houses, and how the energy performance of that building can be improved. A well grounded energy and process audit team should have expertise in the fields of HVAC, structural engineering, electrical and automation engineering, and they should also have a good understanding of production processes.

Most of the knowledge necessary for an energy audit is a part of already existing expertise. Designers, consultants, contractors, and material and equipment suppliers should be familiar with the energy performance of the specific field in which they are experts. Structural designers and consultants should be familiar with heat losses through the building shell and what insulation should be added. Heating and ventilation engineers should be familiar with the energy performance of heating, ventilation, compressed air, and heat recovery systems. Designers of electrical systems should know energy performance of different motors, VFD drives and lighting systems. An industrial process and energy audit requires knowledge of process engineers specialized in certain processes.

Critical to any energy and process audit team member is the ability to apply a “holistic” approach to the energy sources and sinks in the audited target (installation, building, system, or their elements), and the ability to “step outside the box.” This ability presumes a thorough understanding of the processes performed in the audited building, and of the needs of the end users. For this reason, the end users themselves are important members of the team. It is critical for management, production, operations and maintenance (O&M) staff, energy managers, and on-site contractors to “buy in” to the implementation by participating in the process, sharing their knowledge and expertise, gathering information, and developing ideas.

Acronyms and Abbreviations

Term	Spellout
ACSIM	Assistant Chief of Staff for Installation Management
AHU	air handling unit
BMS	Building Management System
BTU	British Thermal Unit
CEP	Central Energy Plant
CERL	Construction Engineering Research Laboratory
CFL	Compact Fluorescent Lamp
cfm	cubic feet per minute
CFR	Code of the Federal Regulations
COP	coefficient of performance
DDC	direct digital control
DH	District Heating
DPW	Directorate of Public Works
ECBCS	Energy Conservation in Buildings and Community Systems
ECM	energy conservation measure
ECSM	Energy Conservation Savings Measure
EFLH	
EMCS	Energy Management Control System
EPACT	Energy Policy Act
EPOA	Energy and Process Optimization Assessment
ERDC	Engineer Research and Development Center
ESPC	Energy Savings Performance Contract
FCU	
FEDS	Facility Energy Decision System
FL	Fluorescent Light
HE	high efficiency
HP	horsepower
HQIMCOM	Headquarters, Installation Management Command
HVAC	heating, ventilating, and air-conditioning
HW	Hot Water
IAQ	indoor air quality
IEA	International Energy Agency
IEQ	indoor environmental quality
IMCOM	Installation Management Command
IR	infrared
IT	Information Technology

Term	Spellout
KAH	Keller Army Hospital
KW	kilowatt
LED	light emitting diode
LPG	liquid petroleum gas
MBH	1000 BTU/hr
MBTU	1000 BTU
MH	Metal Halide
MMBTU	a thousand thousand BTUs
MW	megawatt
MWR	morale, welfare, and recreation
OA	outdoor air
PNNL	Pacific Northwest National Laboratory
psig	pound-force per square inch gauge
PX	Post Exchange
SIR	savings to investment ratio
SME	subject matter expert
TMY	typical meteorological year
TR	Technical Report
UESC	Utility Energy Services Contract
UMCS	Utility Monitoring and Control System
VAV	variable air volume
VFD	variable frequency drive
WWW	World Wide Web

Appendix A: Summary of All ECMs

Legend

Blended Electrical	125	$/MWh
Summer Demand	11.96	$/KW
Winter Demand	8.44	$/KW
Year Demand Avg	9.61	$/KW
Gas	12.39	$/MMBtu
Fuel Oil (Cairnes Field)	1.95	$/Gal
Propane		$/MMBtu
Water	1.694	$/Kgal

PNNL does not use blended electric rates & Thermal energy for many retrofits are more than just natural gas

Table A1. Summary of All ECMs

ECM #	ECM Description	Electricity Savings				Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		MMBtu/yr	KWh/yr	kW Dem	$/yr	MMBtu/yr	$/yr				
BE #1	Establish a Cool Roofs Strategy	2,838	831,800	0	103,975	–1,060	$(13,133)		$90,842		0.0
BE #2	Add Insulated Panels Behind Single Pane Windows, Gillis Field House Building 633	0			0	24	$297		$297	$700	2.4
BE #3	Install Interior Windows in Building 622 (Library) and In the Basement of Building 685	0			0		$–		$0		-
BE #4	Insulate Attic in Southern Part of Building 622	0			0	376	$4,655		$4,655	$50,500	10.8
BE_5A	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	57	16,705	6	1,439	0	$0	$0	$1,439	$12,967	9.0
BE_5B	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–1	–293	2	–19	150	$1,855	$0	$1,836	$9,192	5.0
BE_5C	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–4	–1,172	2	–76	83	$1,029	$0	$953	$4,295	4.5
BE_5D	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	1	293	0	18	33	$410	$0	$428	$4,279	10.0
BE_5E	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–8	–2,345	5	–163	281	$3,478	$0	$3,315	$22,536	6.8
BE_5F	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–38	–11,137	18	–740	807	$10,742	$0	$10,002	$41,725	4.2
BE_5G	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	0	0	0	0	143	$1,771	$0	$1,771	$11,193	6.3
BE_5H	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–9	–2,638	4	–187	212	$2,622	$0	$2,435	$18,204	7.5

ECM #	ECM Description	Electricity Savings				Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		MMBtu/yr	KWh/yr	kW Dem	$/yr	MMBtu/yr	$/yr				
BE_5I	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	0	0	0	0	141	$1,743	$0	$1,743	$19,388	11.1
BE_5J	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	0	0	0	0	155	$1,926	$0	$1,926	$13,099	6.8
BE_5K	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–7	–2,051	8	41	559	$6,921	$0	$6,962	$25,880	3.7
BE_5L	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	–6	–1,758	49	1,218	3,722	$46,121	$0	$47,339	$168,659	3.6
BE_5M	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	26	7,620	5	951	390	$4,830	$0	$5,781	$49,882	8.6
BE_5N	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	5	1,465	4	158	70	$870	$0	$1,028	$8,624	8.4
BE_5O	Insulate Perimeter of Slab on Grade: Increase Insulation by R–15	0	0	0	0	1,307	$19,946	$0	$19,946	$60,310	3.0
BE_6A	Attic Ceiling: Increase Insulation by R–13 (blow–in cellulose)	7	2,051	3	326	0	$0	$0	$326	$3,209	9.8
BE_6B	Attic Ceiling: Increase Insulation by R–13 (blow–in cellulose)	62	18,170	13	2,519	519	$6,426	$0	$8,945	$78,086	8.7
BE_6C	Attic Ceiling: Increase Insulation by R–19 (blow–in cellulose)	3	879	4	266	112	$1,383	$0	$1,649	$15,760	9.6
BE_6D	Attic Ceiling: Increase Insulation by R–30 (blow–in cellulose)	92	26,963	39	5,314	1,965	$24,349	$0	$29,663	$54,199	1.8
BE_6E	Attic Ceiling: Increase Insulation by R–30 (blow–in cellulose)	124	36,341	66	7,389	2,707	$33,544	$0	$40,933	$75,455	1.8
BE_6F	Attic Ceiling: Increase Insulation by R–30 (blow–in cellulose)	0	0	0	0	1,503	$24,996	$0	$24,996	$52,436	2.1
BE_6G	Attic Ceiling: Increase Insulation by R–30 (blow–in cellulose)	0	0	0	0	1,715	$31,407	$0	$31,407	$51,508	1.6
BE_6H	Attic Ceiling: Increase Insulation by R–30 (blow–in cellulose)	0	0	0	0	3,359	$51,287	$0	$51,287	$85,322	1.7
BE_6I	Attic Ceiling: Increase Insulation by R–30 (blow–in cellulose)	15	4,396	9	962	406	$5,032	$0	$5,994	$33,465	5.6
BE_6J	Attic Ceiling: Increase Insulation by R–30 (blow–in cellulose)	83	24,325	20	3,737	672	$8,323	$0	$12,060	$64,029	5.3
BE_6K	Attic Ceiling: Increase Insulation by R–30 (blow–in cellulose)	118	34,582	50	6,233	2,348	$29,086	$0	$35,319	$188,815	5.3
BE_6L	Attic Ceiling: Increase Insulation by R–38 (blow–in cellulose)	189	55,390	58	9,088	2,334	$35,326	$0	$44,414	$77,715	1.7
BE_6M	Attic Ceiling: Increase Insulation by R–38 (blow–in cellulose)	447	131,003	138	21,628	5,578	$78,361	$0	$99,989	$182,706	1.8
BE_6N	Suspended Ceiling: Increase Insulation by R–11	643	188,445	292	18,798	0	$0	$0	$18,798	$77,053	4.1
BE_6O	Suspended Ceiling: Increase Insulation by R–19	8	2,345	0	259	480	$5,951	$0	$6,210	$21,544	3.5
BE_6P	Suspended Ceiling: Increase Insulation by R–19	0	0	0	0	1,653	$20,480	$0	$20,480	$60,029	2.9
BE_6Q	Suspended Ceiling: Increase Insulation by R–19	751	220,096	269	36,446	9,020	$111,764	$0	$148,210	$137,712	0.9

ECM #	ECM Description	Electricity Savings				Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		MMBtu/yr	KWh/yr	kW Dem	$/yr	MMBtu/yr	$/yr				
BE_6R	Suspended Ceiling: Increase Insulation by R−19	4	1,172	4	294	265	$3,287	$0	$3,581	$30,623	8.6
BE_6S	Suspended Ceiling: Increase Insulation by R−19	7	2,051	2	685	480	$8,789	$0	$9,474	$64,222	6.8
BE_6T	Suspended Ceiling: Increase Insulation by R−38	23	6,741	27	1,502	1,388	$17,194	$0	$18,696	$56,294	3.0
BE_6U	Suspended Ceiling: Increase Insulation by R−38	51	14,947	48	4,545	1,511	$18,724	$0	$23,269	$39,202	1.7
BE_6V	Suspended Ceiling: Increase Insulation by R−38	122	35,755	90	7,916	3,221	$39,910	$0	$47,826	$158,134	3.3
BE_6W	Suspended Ceiling: Increase Insulation by R−38	−54	−15,826	251	12,809	4,708	$62,606	$0	$75,415	$155,278	2.1
BE_7A	Add Insulation to Interior Surface of Metal Roof: 4-in. Fiberglass	6,620	1,940,130	1,986	313,768	67,392	$855,393	$0	$1,169,161	$585,439	0.5
BE_7B	Add Insulation to Interior Surface of Metal Roof: 4-in. Fiberglass	65	19,050	48	4,729	1,275	$18,075	$0	$22,804	$189,117	8.3
BE_7C	Insulate Built−up Roof Surface (R−10) and Re−Roof	0	0	0	0	1,074	$13,312	$0	$13,312	$181,451	13.6
BE_7D	Insulate Built−up Roof Surface (R−10) and Re−Roof	0	0	0	0	1,204	$14,915	$0	$14,915	$149,417	10.0
BE_7E	Insulate Built−up Roof Surface (R−10) and Re−Roof	306	89,680	12	10,117	3,873	$47,990	$0	$58,107	$422,738	7.3
BE_7F	Insulate Built−up Roof Surface (R−10) and Re−Roof	0	0	0	0	8,275	$102,532	$0	$102,532	$875,814	8.5
BE_7G	Insulate Built−up Roof Surface (R−15) and Re−Roof	0	0	0	0	2,634	$32,641	$0	$32,641	$298,204	9.1
BE_7H	Insulate Built−up Roof Surface (R−15) and Re−Roof	105	30,772	67	7,610	2,378	$29,468	$0	$37,078	$319,168	8.6
BE_7I	Insulate Built−up Roof Surface (R−15) and Re−Roof	0	0	0	0	4,192	$51,933	$0	$51,933	$473,035	9.1
BE_8A	Add Interior Masonry Surface Insulation: R−12.4	1	293	27	493	2,935	$36,359	$0	$36,852	$425,449	11.5
BE_8B	Blow−in Wall Insulation to Fill Available Space	385	112,832	136	17,840	8,313	$105,507	$0	$123,347	$1,586,611	12.9
BE_8C	Blow−in Wall Insulation to Fill Available Space	19	5,568	26	1,666	1,853	$28,684	$0	$30,350	$353,652	11.7
BE_8D	Blow−in Wall Insulation to Fill Available Space	0	0	0	0	211	$3,502	$0	$3,502	$46,224	13.2
BE_8E	Blow−in Wall Insulation to Fill Available Space	0	0	0	0	541	$9,908	$0	$9,908	$98,217	9.9
BE_8F	Blow−in Wall Insulation to Fill Available Space	0	0	0	0	2,447	$37,362	$0	$37,362	$484,922	13.0
BE_9A	Install Thermal Break Aluminum Frame Double Pane Argon/Low−e Window	−6	−1,758	1	−344	786	$14,391	$0	$14,047	$169,851	12.1
BE_9B	Install Thermal Break Aluminum Frame Double Pane Argon/Low−e Window	−27	−7,913	5	−717	1,074	$13,302	$0	$12,585	$107,073	8.5

ECM #	ECM Description	Electricity Savings				Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		MMBtu/yr	KWh/yr	kW Dem	$/yr	MMBtu/yr	$/yr				
BE_9C	Install Thermal Break Aluminum Frame Double Pane Argon/Low–e Window	0	0	0	0	3,782	$46,863	$0	$46,863	$457,834	9.8
BE_9D	Install Thermal Break Aluminum Frame Double Pane Argon/Low–e Window	0	0	0	0	529	$8,791	$0	$8,791	$80,471	9.2
BE_9E	Install Thermal Break Aluminum Frame Double Pane Argon/Low–e Window	0	0	0	0	940	$17,223	$0	$17,223	$134,378	7.8
BE_9F	Install Thermal Break Aluminum Frame Double Pane Argon/Super Low–e Window	63	18,463	64	4,945	2,283	$28,288	$0	$33,233	$340,578	10.2
BE_9G	Install Wood or Vinyl Frame Double Pane Argon/Low–e Window	521	152,690	211	25,945	12,490	$158,537	$0	$184,482	$1,776,524	9.6
BE_9H	Install Wood or Vinyl Frame Double Pane Argon/Low–e Window	23	6,741	53	3,668	4,332	$67,063	$0	$70,731	$616,872	8.7
BE_9I	Install Wood or Vinyl Frame Double Pane Argon/Low–e Window	15	4,396	55	3,049	3,377	$41,845	$0	$44,894	$540,818	12.0
BE_9J	Install Wood or Vinyl Frame Double Pane Argon/Low–e Window	118	34,582	54	6,334	3,177	$48,068	$0	$54,402	$468,299	8.6
BE_9K	Install Wood or Vinyl Frame Double Pane Argon/Low–e Window	229	67,113	237	17,823	16,128	$199,831	$0	$217,654	$2,342,369	10.8
BE_9L	Install Wood or Vinyl Frame Double Pane Argon/Low–e Window	227	66,527	107	12,324	6,377	$89,582	$0	$101,906	$924,848	9.1
BE_9M	Install Wood or Vinyl Frame Double Pane Argon/Low–e Window	0	0	0	0	1,742	$26,601	$0	$26,601	$264,946	10.0
BE_9N	Install Wood or Vinyl Frame Double Pane Argon/Super Low–e Window	60	17,584	32	3,795	1,460	$18,088	$0	$21,883	$259,222	11.8
BE_9O	Install Wood or Vinyl Frame Double Pane Argon/Super Low–e Window	396	116,056	90	17,880	2,977	$36,884	$0	$54,764	$601,965	11.0
CEP #1	Install Missing Insulation In CEP And Heat Distribution, Repair Leaks	0			0		$–		$0		–
CEP #2	Gas Metering For Main CEP In Building 604	0			0	40,000	$495,600		$495,600	$69,384	0.1
CEP #3	Small Boiler In CEP Building 845 (Laundry Boiler)	0			0	22,680	$281,005		$281,005	$800,850	2.8
CEP #4	Reduce Steam Pressure To A Standardized Mid Or Low Pressure	0			0	3,600	$44,604	$3,000	$47,604	$310,000	6.5
CEP #5	Longer Use Of The Backpressure Steam Turbine By Increasing The Low Pressure Steam Demand	4,094	1,200,000		150,000		$–		$150,000	$240,000	1.6
CEP #6	Interconnect The North And The Central Heating Distribution System	0			0	22,680	$281,005		$281,005	$200,000	0.7
CEP #7	Hot Water Conversion And Replacement Of The Unstable Tunnels	0			0	7,200	$89,208	$240,000	$329,208	$700,000	2.1
CEP #8	Trigen Plant In CEP 604	190,927	55,957,440	5000	7,042,747	–296,000	$(3,667,440)		$3,375,307	28,200,000	8.4

ECM #	ECM Description	Electricity Savings MMBtu/yr	KWh/yr	kW Dem	$/yr	Thermal MMBtu/yr	$/yr	Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
CEP #9_A	Abandon CEP 604 and install heating and hot water systems in buildings	−1,078	−316,046	−305	−30,006	289,127	$3,289,386	275,879	$3,535,259	$3,207,715	0.9
CON #1	Increase / Decrease Space Temperature Setpoints and Make Them Uniform	0			0		$–		$0		–
CON #2	Reduce HVAC Run Time / Schedule AHUs To Match Building Occupancy	293	86,000		10,750	1,233	$15,277		$26,027	20,000	0.8
CON #3	Improved Temperature Control in Kitchen, Building 745	87	25,500		3,188	383	$4,745		$7,933	$5,000	0.6
CON #4	Keller Army Hospital AHUs Retrofit And Controls	2,634	772,000		96,500	16,800	$208,152		$304,652	$200,000	0.7
CON #5	Control Motor VFDs Instead Of Full Constant Speed and Replace Malfunctioning VFDs	358	105,000		13,125		$–		$13,125	$5,000	0.4
CON #6	Remove Pneumatic Thermostats From Spaces With DDC Controls	22	6,500		813		$–		$813	$500	0.6
CON #7	Connect More Mechanical Equipment to EMCS	0			0		$–		$0		–
CON #8	Initiate Night/Weekend and Summer/Winter Setpoint Changes	0			0		$–		$0		–
CON #9	Fix Failed Controls in PX, Building 1204	648	190,000		23,750	3,310	$41,011		$64,761	$85,000	1.3
DIN #1	Modify Kitchen Hoods with End Skirts, Bldg 745	325	95,200		11,900	1,114	$13,802		$25,702	$19,600	0.8
DIN #2	Repair Freezer Door Sears, Building 745	143	41,800		5,225		$–		$5,225	$20,000	3.8
DIN #3	Heat Recovery from Refrigeration Machines, Building 745	0			0	3,100	$38,409		$38,409	$85,000	2.2
EL #1	Use Energy Efficient Electric Motors; Buildings 750, 5102, 5440, 6901	59	17,350		2,169		$–		$2,169	$3,150	1.5
EL #2	Switch off Computers When Not In Use	1,989	582,920		72,865		$–		$72,865	$0	0.0
HVAC #1	Glycol heat recovery change	0			0	682	$8,450		$8,450	5,000	0.6
HVAC #2	Heat Recovery from Computer Room Air–conditioning	0			0	2,047	$25,362		$25,362	50,000	2.0
HVAC #3A	New Solutions for Re–heat Condenser Heat, Building 655	3,873	1,135,000		141,875	2,867	$35,522		$177,397	323,000	1.8
HVAC #3B	New Solutions for Re–heat Heat Exchanger, Building 655	3,849	1,128,200		141,025	2,867	$35,522		$176,547	483,000	2.7
HVAC #3C	New Solutions for Re–heat Bypass Cooling Coil, Building 655	3,873	1,135,000		141,875	2,867	$35,522		$177,397	317,000	1.8
HVAC #4	Re–Commissioning Of HVAC Systems And Controls	53,739	15,750,000		1,968,750	70,313	$871,172		$2,839,922	160,000	0.1

ECM #	ECM Description	Electricity Savings				Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		MMBtu/yr	KWh/yr	kW Dem	$/yr	MMBtu/yr	$/yr				
HVAC #5	Use Existing Steam Absorption Chiller And Supplement With Small Electric Chiller At Hospital	0			0		$–		$0	(300,000)	–
HVAC #6	Switch Off Boilers in Holleder Center; Use Local Gas Burners to Re-generate Desiccant Wheel in De–humidifier	220	64,500		8,063	900	$11,151		$19,214	10,000	0.5
HVAC #7	Use Waste Heat from Ice Makers / Use Condenser Heat in the Holleder Building to Pre–heat Outdoor Air	0			0		$–		$0		–
HVAC #8	Do Not Replace AHUs at the Keller Army Hospital	0			0		$–		$500,000	500,000	1.0
HVAC #9	Install CO_2 Controls In The Keller Army Hospital	191	56,000		7,000	6,100	$75,579		$82,579	100,000	1.2
HVAC_10A	Replace Existing Boiler with Condensing Gas Boiler – 91% Combus-tion Efficiency	0	0	0	0	718	$8,901	–132	$8,769	60,457	6.9
HVAC_10B	Replace Existing Boiler with Condensing Gas Boiler – 91% Combus-tion Efficiency	0	0	0	0	708	$8,766	–257	$8,509	49,286	5.8
HVAC_10C	Replace Existing Boiler with Condensing Gas Boiler – 91% Combus-tion Efficiency	1	293	0	27	578	$29,003	–998	$28,032	70,449	2.5
HVAC_10D	Replace Existing Boiler with Conventional Gas Boiler – 84% Combus-tion Efficiency	0	0	0	0	206	$2,554	1,815	$4,369	48,301	11.1
HVAC_10E	Replace Existing Boiler with Conventional Gas Boiler – 84% Combus-tion Efficiency	0	0	0	0	176	$2,178	27	$2,205	16,485	7.5
HVAC_10F	Replace Existing Boiler with Conventional Gas Boiler – 84% Combus-tion Efficiency	0	0	0	0	106	$1,313	268	$1,581	9,190	5.8
HVAC_10G	Replace Existing Boiler with Conventional Gas Boiler – 84% Combus-tion Efficiency	0	0	0	0	209	$13,527	402	$13,929	33,628	2.4
HVAC_10H	Replace Existing Boiler with Conventional Gas Boiler – 84% Combus-tion Efficiency	0	0	0	0	95	$9,686	590	$10,276	32,190	3.1
HVAC_10I	Replace Existing Boiler with Conventional Gas Boiler – 84% Combus-tion Efficiency	0	0	0	0	40	$2,373	29	$2,402	5,258	2.2
HVAC_10J	Replace Existing Boiler with Conventional Gas Boiler – 84% Combus-tion Efficiency	0	0	0	0	86	$5,568	251	$5,819	13,326	2.3

ECM #	ECM Description	Electricity Savings				Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		MMBtu/yr	KWh/yr	kW Dem	$/yr	MMBtu/yr	$/yr				
HVAC_10K	Replace Existing Boiler with Conventional LPG Boiler – 84% Combustion Efficiency	0	0	0	0	605	$11,079	884	$11,963	66,056	5.5
HVAC_11A	Replace Existing Boiler with LPG Infrared Heating System – High Efficiency	0	0	0	0	2,209	$40,467	3,181	$43,648	142,828	3.3
HVAC_11B	Replace Existing Furnace with LPG Infrared Heating System – High Efficiency	0	0	0	0	1,163	$21,310	1,141	$22,451	104,383	4.6
HVAC_11C	Replace Existing Steam AHU with Natural Gas Infrared Heating System – High Efficiency	–5	–1,465	0	–152	125	$2,961	–132	$2,677	13,223	4.9
HVAC_11D	Replace Existing Steam FCU with Natural Gas Infrared Heating System – High Efficiency	–11	–3,224	0	–346	295	$6,957	–311	$6,300	31,059	4.9
HVAC_11E	Replace Existing Boiler with Natural Gas Infrared Heating System – High Efficiency	–6	–1,758	0	–189	314	$7,275	413	$7,499	16,606	2.2
HVAC_11F	Replace Existing Boiler with Natural Gas Infrared Heating System – Medium Efficiency	0	0	0	0	1,015	$21,521	4,290	$25,811	57,832	2.2
HVAC_12A	Replace Existing Furnace with Condensing Gas Furnace – 92% Efficient	9	2,638	0	312	2,151	$26,654	–949	$26,017	177,576	6.8
HVAC_12B	Replace Existing Furnace with Condensing Gas Furnace – 92% Efficient	–114	–33,410	0	–3,776	1,086	$13,458	–484	$9,198	87,865	9.6
HVAC_12C	Replace Existing Furnace with Condensing LPG Furnace – 92% Efficient	–39	–11,430	0	–1,314	340	$6,086	–255	$4,517	40,349	8.9
HVAC_12D	Replace Existing Furnace with Condensing LPG Furnace – 92% Efficient	–5	–1,465	0	–159	48	$873	–38	$676	5,996	8.9
HVAC_13A	Add Automatic Electric Damper to Existing Boilers	0	0	0	0	117	$1,449	–15	$1,434	771	0.5
HVAC_13B	Add Automatic Electric Damper to Existing Boilers	0	0	0	0	46	$569	–5	$564	248	0.4
HVAC_13C	Add Automatic Electric Damper to Existing Boilers	0	0	0	0	229	$2,840	–62	$2,778	3,095	1.1
HVAC_13D	Add Automatic Electric Damper to Existing Boilers	0	0	0	0	243	$3,014	–26	$2,988	1,290	0.4
HVAC_13E	Add Automatic Electric Damper to Existing Boilers	0	0	0	0	81	$999	–44	$955	2,184	2.3
HVAC_13F	Add Automatic Electric Damper to Existing Boilers	0	0	0	0	4	$45	–1	$44	31	0.7

ECM #	ECM Description	Electricity Savings				Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		MMBtu/yr	KWh/yr	kW Dem	$/yr	MMBtu/yr	$/yr				
HVAC_13G	Add Automatic Electric Damper to Existing Boilers	0	0	0	0	41	$758	–22	$736	1,121	1.5
HVAC_14A	Replace existing with Single Zone Packaged AC Unit (very high efficiency / medium)	315	92,317	26	11,754	0	$–	54	$11,808	87,243	7.4
HVAC_14B	Replace Existing Chiller with Water–Cooled Centrifugal Electric Chiller (ultra high efficiency)	136	39,858	35	6,249	0	$–	1,035	$7,284	103,410	14.2
HVAC_14C	Replace Existing Chiller with Water–Cooled Reciprocating Electric Chiller (high efficiency) and Cooling Tower	136	39,858	34	6,422	0	$–	–3	$6,419	75,658	11.8
LI #1	Use Occupancy Sensors to Shut off Lights, Buildings 663, 714 727 & Various Barracks	1,242	363,886		45,486		$–		$45,486	$48,900	1.1
LI #2	Shut Off Exterior Lights During Daytime	131	38,300		4,788		$–		$4,788	$1,000	0.2
LI #3	Shut off Interior Lights during Daytime in Areas that are Bright from Daylight	20	6,000		750		$–		$750	$1,000	1.3
LI #4	Replace Incandescent Lights With CFL (Buildings 685, 622, 714)	116	34,000		4,250		$–		$4,250	$2,000	0.5
LI_5A	Replace incandescent lights with CFL	11	3,224	1	432	0	$–	$141	$573	$186	0.3
LI_5B	Replace incandescent lights with CFL	14	4,103	0	474	0	$–	$175	$649	$340	0.5
LI_5C	Replace incandescent lights with CFL	461	135,106	19	16,339	–268	$(3,326)	$5,335	$18,348	$10,358	0.6
LI_5D	Replace incandescent lights with CFL	27	7,913	4	974	0	$–	$279	$1,253	$2,087	1.7
LI_5E	Replace incandescent lights with CFL	168	49,236	7	5,980	–74	$(920)	$1,881	$6,941	$2,597	0.4
LI_5F	Replace incandescent lights with CFL	131	38,392	17	4,675	0	0	1,838	$6,513	$8,904	1.4
LI_5G	Replace incandescent lights with CFL	1,796	526,356	100	67,184	–995	$(15,197)	22,711	$74,698	$28,602	0.4
LI_5H	Replace incandescent lights with CFL	384	112,539	50	14,787	0	0	4,938	$19,725	$14,610	0.7
LI_5I	Replace incandescent lights with CFL	490	143,605	32	18,919	–86	$(1,069)	$5,122	$22,972	$7,267	0.3
LI_5J	Replace incandescent lights with CFL	1,341	393,008	114	53,864	–643	$(7,971)	$16,713	$62,606	$36,565	0.6
LI_5K	Replace incandescent lights with CFL	1	293	0	57	0	$–	$22	$79	$31	0.4
LI_5L	Replace incandescent lights with CFL	2	586	0	81	0	$–	$35	$116	$186	1.6
LI_5M	Replace incandescent lights with CFL	698	204,564	35	23,899	–428	$(5,306)	$9,307	$27,900	$15,259	0.5

ECM #	ECM Description	Electricity Savings				Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		MMBtu/yr	KWh/yr	kW Dem	$/yr	MMBtu/yr	$/yr				
LI_5N	Replace incandescent lights with CFL	2,264	663,513	121	80,834	−1,707	$(21,669)	$30,713	$89,878	$50,355	0.6
LI_5O	Replace incandescent lights with CFL	794	232,698	41	27,318	−572	$(8,858)	$10,743	$29,203	$17,767	0.6
LI_5P	Replace incandescent lights with CFL	1,810	530,459	71	62,315	−1,000	$(12,388)	$24,527	$74,454	$40,562	0.5
LI_5Q	Replace incandescent lights with CFL	713	208,960	36	24,551	−447	$(5,537)	$9,634	$28,648	$15,932	0.6
LI_5R	Replace incandescent lights with CFL	597	174,963	33	20,567	−360	$(4,458)	$8,175	$24,284	$13,520	0.6
LI_5S	Replace incandescent lights with CFL	621	181,997	32	21,392	−424	$(6,423)	$8,342	$23,311	$13,677	0.6
LI_5T	Replace incandescent lights with CFL	1,794	525,769	91	61,778	−1,132	$(14,031)	$24,107	$71,854	$39,867	0.6
LI_5U	Replace incandescent lights with CFL	240	70,337	9	8,211	−145	$(1,792)	$3,208	$9,627	$5,260	0.5
LI_5V	Replace incandescent lights with CFL	1,262	369,856	67	43,550	−897	$(12,595)	$17,155	$48,110	$28,371	0.6
LI_5W	Replace incandescent lights with CFL	4,992	1,463,011	334	179,577	−2,261	$(41,420)	$66,393	$204,550	$75,935	0.4
LI_5X	Replace incandescent lights with CFL	16	4,689	1	575	0	$–	$184	$759	$2,640	3.5
LI_5Y	Replace incandescent lights with CFL	17	4,982	1	574	0	$–	$105	$679	$396	0.6
LI_5Z	Replace incandescent lights with CFL	44	12,895	3	1,738	0	$–	$791	$2,529	$969	0.4
LI_5AA	Replace incandescent lights with CFL	37	10,844	4	1,469	−24	$(293)	$1,012	$2,188	$1,159	0.5
LI_5AB	Replace incandescent lights with CFL	9	2,638	1	354	−7	$(83)	$190	$461	$186	0.4
LI_6A	Replace existing exit signs with electroluminescent exit signs	725	212,477	24	25,320	0	$–	$14,772	$40,092	$40,166	1.0
LI_6B	Replace existing exit signs with electroluminescent exit signs	120	35,169	1	4,161	0	$–	$2,317	$6,478	$6,301	1.0
LI_6C	Replace existing exit signs with electroluminescent exit signs	57	16,705	2	1,986	−33	$(405)	$1,159	$2,740	$3,150	1.1
LI_6D	Replace existing exit signs with electroluminescent exit signs	57	16,705	2	1,986	−33	$(405)	$1,159	$2,740	$3,150	1.1
LI_6E	Replace existing exit signs with electroluminescent exit signs	1,233	361,357	56	43,999	−939	$(11,917)	$22,882	$54,964	$62,218	1.1
LI_6F	Replace existing exit signs with electroluminescent exit signs	222	65,062	9	7,875	−161	$(2,484)	$4,055	$9,446	$11,026	1.2
LI_6G	Replace existing exit signs with electroluminescent exit signs	423	123,969	19	15,112	−255	$(3,156)	$7,820	$19,776	$21,264	1.1
LI_6H	Replace existing exit signs with electroluminescent exit signs	378	110,781	17	13,503	−264	$(3,989)	$6,952	$16,466	$18,902	1.1
LI_6I	Replace existing exit signs with electroluminescent exit signs	601	176,136	27	21,428	−426	$(5,980)	$11,007	$26,455	$29,928	1.1

ECM #	ECM Description	Electricity Savings MMBtu/yr	Electricity Savings KWh/yr	Electricity Savings kW Dem	Electricity Savings $/yr	Thermal MMBtu/yr	Thermal $/yr	Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
LI_6J	Replace existing exit signs with electroluminescent exit signs	394	115,470	13	13,736	−44	$(539)	$8,014	$21,211	$21,790	1.0
LI_6K	Replace existing exit signs with electroluminescent exit signs	106	31,066	4	3,790	−30	$(378)	$2,124	$5,536	$5,776	1.0
LI_6L	Replace existing exit signs with electroluminescent exit signs	16	4,689	1	574	−7	$(82)	$290	$782	$788	1.0
LI_6M	Replace existing exit signs with electroluminescent exit signs	44	12,895	2	1,557	−23	$(288)	$772	$2,041	$2,100	1.0
LI_6N	Replace existing exit signs with electroluminescent exit signs	14	4,103	0	490	−3	$(39)	$290	$741	$788	1.1
LI_6O	Replace existing exit signs with electroluminescent exit signs	189	55,390	6	6,664	−77	$(1,405)	$3,476	$8,735	$9,451	1.1
LI_6P	Replace existing exit signs with electroluminescent exit signs	228	66,820	8	7,944	−166	$(2,057)	$4,634	$10,521	$12,601	1.2
LI_6Q	Replace existing exit signs with electroluminescent exit signs	199	58,321	7	6,950	−135	$(1,672)	$4,055	$9,333	$11,026	1.2
LI_6R	Replace existing exit signs with electroluminescent exit signs	49	14,360	2	1,737	−25	$(307)	$2,885	$4,315	$3,150	0.7
LI_6S	Replace existing exit signs with electroluminescent exit signs	227	66,527	8	7,920	0	$–	$15,387	$23,307	$16,802	0.7
LI_6T	Replace existing exit signs with electroluminescent exit signs	109	31,945	5	3,862	−55	$(782)	$4,813	$7,893	$15,751	2.0
LI_6U	Replace existing exit signs with electroluminescent exit signs	275	80,595	12	9,785	−93	$(1,234)	$11,550	$20,101	$37,804	1.9
LI_6V	Replace existing exit signs with electroluminescent exit signs	31	9,085	1	1,090	−12	$(146)	$1,444	$2,388	$4,725	2.0
LI_6W	Replace existing exit signs with electroluminescent exit signs	11	3,224	0	382	0	$–	$481	$863	$1,575	1.8
LI_6X	Replace existing exit signs with electroluminescent exit signs	27	7,913	1	950	−19	$(233)	$1,444	$2,161	$4,725	2.2
LI_6Y	Replace existing exit signs with electroluminescent exit signs	1	293	0	46	−1	$(9)	$202	$239	$1,575	6.6
LI_6Z	Replace existing exit signs with electroluminescent exit signs	2	586	0	69	−1	$(14)	$304	$359	$2,363	6.6
LI_6AA	Replace existing exit signs with electroluminescent exit signs	11	3,224	1	401	−5	$(64)	$1,822	$2,159	$14,176	6.6
LI_6AB	Replace existing exit signs with electroluminescent exit signs	4	1,172	0	126	−2	$(20)	$506	$612	$3,938	6.4
LI_6AC	Replace existing exit signs with electroluminescent exit signs	2	586	0	82	−1	$(9)	$405	$478	$3,150	6.6
LI_6AD	Replace existing exit signs with electroluminescent exit signs	11	3,224	0	397	−6	$(77)	$1,619	$1,939	$12,601	6.5
LI_6AE	Replace existing exit signs with electroluminescent exit signs	4	1,172	0	124	−3	$(33)	$607	$698	$4,725	6.8
LI_6AF	Replace existing exit signs with electroluminescent exit signs	9	2,638	0	310	−2	$(24)	$1,518	$1,804	$11,814	6.5
LI_6AG	Replace existing exit signs with electroluminescent exit signs	0	0	0	7	0	$(1)	$34	$40	$263	6.6

ECM #	ECM Description	Electricity Savings MMBtu/yr	Electricity Savings KWh/yr	Electricity Savings kW Dem	Electricity Savings $/yr	Thermal MMBtu/yr	Thermal $/yr	Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
LI_6AH	Replace existing exit signs with electroluminescent exit signs	2	586	0	55	–1	$(14)	$270	$311	$2,100	6.8
LI_6AI	Replace existing exit signs with electroluminescent exit signs	2	586	0	83	0	$–	$405	$488	$3,150	6.5
LI_6AJ	Replace existing exit signs with electroluminescent exit signs	3	879	0	122	–1	$(7)	$506	$621	$3,938	6.3
LI_6AK	Replace existing exit signs with electroluminescent exit signs	20	5,861	1	717	–5	$(58)	$2,834	$3,493	$22,052	6.3
LI_7A	Replace T8 lighting with Super T8 lighting	171	50,115	14	6,877	–37	$(461)	$842	$7,258	$39,565	5.5
LI_7B	Replace T8 lighting with Super T8 lighting	458	134,227	38	18,277	–146	$(1,804)	$3,428	$19,901	$78,108	3.9
LI_7C	Replace T8 lighting with Super T8 lighting	25	7,327	2	896	–4	$(46)	$134	$984	$6,058	6.2
LI_7D	Replace T8 lighting with Super T8 lighting	104	30,479	5	3,809	0	$–	$1,847	$5,656	$72,579	12.8
LI_7E	Replace T8 lighting with Super T8 lighting	134	39,272	11	5,082	–42	$(516)	$2,163	$6,729	$80,061	11.9
LI_7F	Replace T8 lighting with Super T8 lighting	199	58,321	6	6,946	0	$–	$15	$6,961	$49,017	7.0
LI_7G	Replace T8 lighting with Super T8 lighting	208	60,959	9	7,588	–56	$(694)	$1,259	$8,153	$69,964	8.6
LI_7H	Replace T8 lighting with Super T8 lighting	41	12,016	3	1,503	–6	$(76)	$76	$1,503	$21,263	14.1
LI_7I	Replace T8 lighting with Super T8 lighting	33	9,671	2	1,257	–6	$(78)	$52	$1,231	$15,520	12.6
LI_7J	Replace T8 lighting with Super T8 lighting	510	149,466	26	18,430	0	$–	$7,682	$26,112	$254,576	9.7
LI_7K	Replace T8 lighting with Super T8 lighting	286	83,818	23	11,368	–93	$(1,148)	$1,053	$11,273	$109,659	9.7
LI_7L	Replace T8 lighting with Super T8 lighting	588	172,326	43	22,922	–247	$(3,060)	$2,470	$22,332	$202,215	9.1
LI_7M	Replace T8 lighting with Super T8 lighting	243	71,216	22	9,532	–148	$(1,833)	$3,748	$11,447	$151,553	13.2
LI_7N	Replace T8 lighting with Super T8 lighting	19	5,568	1	734	–11	$(134)	$39	$639	$5,808	9.1
LI_8A	Replace MH with Biaxial Florescent lighting	374	109,609	31	14,963	–100	$(1,236)	$4,701	$18,428	$145,713	7.9
LI_8B	Replace MH with Biaxial Florescent lighting	173	50,701	12	6,344	–32	$(391)	$2,541	$8,494	$70,963	8.4
LI_8C	Replace MH with Biaxial Florescent lighting	95	27,842	6	3,472	–17	$(215)	$1,391	$4,648	$38,846	8.4
LI_8D	Replace MH with High Efficient Electronic ballast MH lighting	5	1,465	0	157	0	$–	$511	$668	$8,021	12.0
LI_9A	Replace T12 with Super T8 lighting	489	143,312	41	19,532	–297	$(3,682)	$4,616	$20,466	$114,564	5.6
LI_9B	Replace T12 with Super T8 lighting	1,744	511,116	72	61,718	–1,180	$(14,620)	$13,355	$60,453	$149,602	2.5

ECM #	ECM Description	Electricity Savings MMBtu/yr	Electricity Savings KWh/yr	Electricity Savings kW Dem	Electricity Savings $/yr	Thermal MMBtu/yr	Thermal $/yr	Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
LI_9C	Replace T12 with Super T8 lighting	119	34,875	6	4,157	–83	$(1,055)	$1,583	$4,685	$27,430	5.9
LI_9D	Replace T12 with Super T8 lighting	42	12,309	2	1,432	–28	$(432)	$611	$1,611	$9,678	6.0
LI_9E	Replace T12 with Super T8 lighting	95	27,842	4	3,259	–49	$(602)	$1,395	$4,052	$22,096	5.5
LI_9F	Replace T12 with Super T8 lighting	37	10,844	2	1,280	–22	$(269)	$548	$1,559	$8,679	5.6
LI_9G	Replace T12 with Super T8 lighting	31	9,085	2	1,077	–17	$(216)	$465	$1,326	$7,365	5.6
LI_9H	Replace T12 with Super T8 lighting	17	4,982	1	592	–11	$(166)	$228	$654	$3,944	6.0
LI_9I	Replace T12 with Super T8 lighting	94	27,549	5	3,244	–55	$(681)	$1,371	$3,934	$21,717	5.5
LI_9J	Replace T12 with Super T8 lighting	13	3,810	0	432	–7	$(87)	$165	$510	$2,865	5.6
LI_9K	Replace T12 with Super T8 lighting	66	19,343	3	2,283	–43	$(614)	$976	$2,645	$15,455	5.8
LI_9L	Replace T12 with Super T8 lighting	1,443	422,902	123	58,276	–368	$(4,891)	$21,417	$74,802	$372,718	5.0
LI_9M	Replace T12 with Super T8 lighting	55	16,119	2	1,991	–23	$(377)	$9,079	$10,693	$120,131	11.2
LI_9N	Replace T12 with Super T8 lighting	54	15,826	2	1,956	–26	$(479)	$8,919	$10,396	$118,006	11.4
LI_10A	Replace metal halide high–bay lighting with T5 lighting	54	15,826	4	2,133	–	$–	4,136	$6,269	21,429	3.4
LI_10B	Replace metal halide high–bay lighting with T5 lighting	65	19,050	3	2,371	(24)	$(297)	1,154	$3,228	16,434	5.1
REN #1	Barracks Shower Hot Water Heat Recovery	0			0	2,700	$33,453		$33,453	245,000	7.3
WATER #1	Fix Cooling Tower Leaks	–34	–10,000		–1,250		$–		$34,540	140,000	4.1
SHW_1A	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank	1,583	463,932	55	55,531	(1,297)	$(16,074)	–249	$39,208	29,359	0.7
SHW_1B	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank	0	0	0	0	39	$480	–28	$452	3,639	8.1
SHW_1C	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank	0	0	0	0	1,838	$22,771	–14	$22,757	18,042	0.8
SHW_1D	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank	0	0	0	0	2,778	$34,416	133	$34,549	20,278	0.6
SHW_1E	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank, Aerators	0	0	0	0	147	$4,259	–62	$4,197	7,526	1.8

ECM #	ECM Description	Electricity Savings				Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		MMBtu/yr	KWh/yr	kW Dem	$/yr	MMBtu/yr	$/yr				
SHW_1F	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank, LFSHs	561	164,413	0	17,424	(439)	$(5,434)	–116	$11,874	20,220	1.7
SHW_1G	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank, LFSHs	0	0	0	0	530	$6,569	–101	$6,468	10,965	1.7
SHW_1H	Replace existing water heaters with Condensing LPG Boiler – 91% Combustion Efficiency, Wrap Tank, Aerators	0	0	0	0	190	$3,488	3	$3,491	4,099	1.2
SHW_1I	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank, LFSHs, Aerators	858	251,455	30	29,989	(731)	$(9,052)	–143	$20,794	20,163	1.0
SHW_1J	Replace existing water heaters with Condensing Gas Boiler – 91% Combustion Efficiency, Wrap Tank, LFSHs, Aerators	0	0	0	0	587	$7,272	–112	$7,160	19,505	2.7
SHW_1K	Replace existing water heaters with Conventional Gas Boiler – 84% Combustion Efficiency, Wrap Tank	524	153,569	22	18,798	(498)	$(6,166)	63	$12,695	29,961	2.4
SHW_1L	Replace existing water heaters with Conventional Distillate Oil Boiler – 86.5% Combustion Efficiency, Wrap Tank, Aerators	0	0	0	0	1,164	$24,970	335	$25,305	25,936	1.0
SHW_2A	Wrap Tank with Insulation, LFSHs	0	0	0	0	106	$1,758	0	$1,758	448	0.3
SHW_2B	Install Faucet Aerators	30	8,792	3	1,259	–	$–	0	$1,259	266	0.2
SHW_2C	Wrap Tank with Insulation	0	0	0	0	14	$236	0	$236	16	0.1
SHW_2D	Wrap Tank with Insulation	0	0	0	0	46	$573	0	$573	134	0.2
SHW_2E	Wrap Tank with Insulation	0	0	0	0	71	$883	0	$883	106	0.1
SHW_2F	Wrap Tank with Insulation, Aerators	0	0	0	0	110	$1,822	0	$1,822	287	0.2
SHW_2G	Wrap Tank with Insulation, Aerators	0	0	0	0	33	$550	0	$550	87	0.2
SHW_2H	Wrap Tank with Insulation, Aerators, Lower Tank Temperature	0	0	0	0	1	$11	0	$11	23	2.1
SHW_2I	Wrap Tank with Insulation, Aerators, Lower Tank Temperature	0	0	0	0	14	$169	0	$169	231	1.4
SHW_2J	Wrap Tank with Insulation, Insulate Pipe Near Tank, Aerators	19	5,568	2	800	–	$–	0	$800	969	1.2
SHW_2K	Wrap Tank with Insulation, Insulate Pipe Near Tank, Aerators	10	2,931	1	452	–	$–	0	$452	229	0.5
SHW_2L	Wrap Tank with Insulation, Insulate Pipe Near Tank, Aerators, Lower Tank Temperature	69	20,222	2	2,411	–	$–	0	$2,411	9,185	3.8

ECM #	ECM Description	Electricity Savings				Thermal		Maintenance $/yr	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment $	Simple Payback yrs
		MMBtu/yr	KWh/yr	kW Dem	$/yr	MMBtu/yr	$/yr				
SHW_2M	Wrap Tank with Insulation, Insulate Pipe Near Tank, Aerators, Lower Tank Temperature	63	18,463	3	2,309	–	$–	0	$2,309	3,541	1.5
SHW_2N	Wrap Tank with Insulation, Insulate Pipe Near Tank, Aerators, Lower Tank Temperature	55	16,119	0	1,712	–	$–	0	$1,712	6,197	3.6
SHW_2O	Wrap Tank with Insulation, Insulate Pipe Near Tank, Aerators, Lower Tank Temperature	13	3,810	1	499	–	$–	0	$499	656	1.3
SHW_2P	Wrap Tank with Insulation, Insulate Pipe Near Tank, LFSHs, Aerators, Lower Tank Temperature	230	67,406	9	8,068	–	$–	0	$8,068	4,644	0.6
SHW_2Q	Wrap Tank with Insulation, Insulate Pipe Near Tank, LFSHs, Aerators, Lower Tank Temperature	1,329	389,491	52	46,446	–	$–	0	$46,446	27,192	0.6
SHW_2R	Wrap Tank with Insulation, Insulate Pipe Near Tank, LFSHs, Aerators, Lower Tank Temperature	380	111,367	15	13,303	–	$–	0	$13,303	7,876	0.6
SHW_2S	Wrap Tank with Insulation, Insulate Pipe Near Tank, LFSHs, Aerators, Lower Tank Temperature	242	70,923	10	8,464	–	$–	0	$8,464	4,976	0.6
SHW_2T	Wrap Tank with Insulation, Insulate Pipe Near Tank, LFSHs, Aerators, Lower Tank Temperature	404	118,401	16	14,142	–	$–	0	$14,142	8,261	0.6
SHW_2U	Wrap Tank with Insulation, Insulate Pipe Near Tank, LFSHs, Aerators, Lower Tank Temperature	639	187,272	25	22,371	–	$–	0	$22,371	13,080	0.6
SHW_2V	Wrap Tank with Insulation, LFSHs, Aerators, Lower Tank Temperature	0	0	0	0	120	$1,492	0	$1,492	1,223	0.8
SHW_2W	Wrap Tank with Insulation, LFSHs, Lower Tank Temperature	0	0	0	0	381	$4,723	0	$4,723	5,097	1.1
SHW_2X	Wrap Tank with Insulation, LFSHs, Lower Tank Temperature	0	0	0	0	562	$6,963	0	$6,963	5,284	0.8
SHW_2Y	Wrap Tank with Insulation, LFSHs, Lower Tank Temperature	0	0	0	0	1,596	$19,772	0	$19,772	15,640	0.8
SHW_2Z	Wrap Tank with Insulation, LFSHs, Lower Tank Temperature	0	0	0	0	86	$1,069	0	$1,069	1,154	1.1
Totals		*316,716*	*92,824,112*	*11,712*	*11,797,496*	*427,230*	*5,231,080*	*1,051,794*	*18,616,159*	*58,316,715*	*3.1*

Table A2. Totals from Tbl. A1.

	Electricity Savings MMBtu/yr	Thermal KWh/yr	Maint kW Demand	Total Savings: Electrical Use, Elec Demand, Thermal, and Maint $/yr	Investment MMBtu/yr	Simple Payback $/yr	$/yr	$/yr	$	yrs	#ECMs	No.	#ECMs	No.
BE_5 Totals	16	4,689	103	2,640	8,053	104,264	0	106,904	470,233	4.4	68	4	BE	72
BE_6 Totals	2,695	789,827	1,383	140,716	45,944	618,225	0	758,941	1,762,796	2.3	0	0	COM	0
BE_7 Totals	7,096	2,079,632	2,113	336,224	92,297	1,166,259	0	1,502,483	3,494,383	2.3	0	9	CON	9
BE_8 Totals	405	118,694	189	19,999	16,300	221,322	0	241,321	2,995,075	12.4	0	3	DIN	3
BE_9 Totals	1,619	474,482	909	94,702	61,454	815,357	0	910,059	9,086,048	10.0	0	0	EC	0
CEP_9 Totals	−1,078	−316,046	−305	−30,006	289,127	3,289,386	275,879	3,535,259	3,207,715	0.9	1	8	CEP	9
HVAC_10 Totals	1	293	0	27	3,527	94,948	2,879	97,854	404,626	4.1	0	2	EL	2
HVAC_11 Totals	−22	−6,448	0	−687	5,121	100,491	8,582	108,386	365,931	3.4	31	11	HVAC	42
HVAC_12 Totals	−149	−43,668	0	−4,937	3,625	47,071	−1,726	40,408	311,786	7.7	99	4	LI	103
HVAC_13 Totals	0	0	0	0	761	9,674	−175	9,499	8,740	0.9	0	1	REN	1
HVAC_14 Totals	587	172,033	95	24,425	0	0	1,086	25,511	266,311	10.4	1	1	Water	2
LI_5 Totals	20,733	6,076,536	1,224	742,468	−11,470	−163,336	273,776	852,908	433,588	0.5	38	0	SHW	38
LI_6 Totals	5,806	1,701,571	229	205,340	−2,828	−37,828	144,814	312,326	430,802	1.4				
LI_7 Totals	3,019	884,782	205	115,221	−796	−9,850	24,808	130,179	1,155,946	8.9				
LI_8 Totals	647	189,617	49	24,936	−149	−1,842	9,144	32,238	263,543	8.2				
LI_9 Totals	4,299	1,259,913	265	161,229	−2,209	−28,171	64,728	197,786	994,250	5.0				
LI_10 Totals	119	34,875	7	4,504	−24	−297	5,290	9,497	37,863	4.0				
SHW_1 Totals	3,526	1,033,369	107	121,742	4,308	67,499	−291	188,950	209,693	1.1				
SHW_2 Totals	3,483	1,020,767	139	122,236	3,140	40,021	0	162,257	116,802	0.7				

Appendix B: Building Designations

Figure B1. Building envelope building designations.

Building Designation	Buildings Affected
BE_5A	601
BE_5B	752, 757
BE_5C	667
BE_5D	667
BE_5E	600, 606, 607, 685
BE_5F	147, 329, 622, 626, 630, 639, 681, 684, 692, 705, 747, 781, 783, 791, 1236, 1330, 1713
BE_5G	753
BE_5H	1, 602, 674, 735
BE_5I	738, 740, 756
BE_5J	620, 624, 751
BE_5K	134, 136, 138, 139, 142, 628, 652, 654, 656, 662, 664
BE_5L	525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 585, 587, 1015, 3002, 3003, 3009, 3011, 3012, 3017, 3019, 3020, 3021, 3022, 3023, 3024, 3025, 3026, 3027, 3028, 3029, 3030, 3031, 3032, 3033, 3034, 3035, 3036, 3037, 3038, 3039, 3040, 3041, 3042, 3043, 3044, 3045, 3046, 3047, 3048, 3049, 3050, 3051, 3052, 3053, 3054, 3055, 3056, 3057, 3058, 3059, 3060, 3061, 3062, 3063, 3064, 3065, 3066, 3067, 3068, 3069, 3070, 3071, 3072, 3073, 3074, 3075, 3076, 3077, 3078, 3079, 3080, 3081, 3083, 3084, 3085, 3086, 3087, 3088
BE_5M	646, 665, 670, 687, 719, 733, 793, 795, 901, 1568, 1720
BE_5N	727
BE_5O	609, 610, 614, 618, 631, 635, 637, 671, 675, 689, 693, 696, 703, 718, 724, 729, 732, 762, 763, 765, 767, 771, 799, 805, 1183, 1230, 1290, 1296, 2018, 2028, 0671A, 0707A
BE_6A	1556, 1558, 1562, 1580, 1592, 1800
BE_6B	646, 665, 670, 687, 719, 733, 793, 795, 901, 1568, 1720
BE_6C	785, 2113
BE_6D	40, 114, 421, 422
BE_6E	21, 25, 42, 45, 48, 109, 126, 170, 173, 208, 216, 249
BE_6F	845
BE_6G	144, 603, 634, 721
BE_6H	609, 610, 614, 618, 631, 635, 637, 671, 675, 689, 693, 696, 703, 718, 724, 729, 732, 762, 763, 765, 767, 771, 799, 805, 1183, 1230, 1290, 1296, 2018, 2028, 0671A, 0707A
BE_6I	134, 136, 138, 139, 142, 628, 652, 654, 656, 662, 664
BE_6J	562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 586, 588, 589, 1012
BE_6K	525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 585, 587, 1015, 3002, 3003, 3009, 3011, 3012, 3017, 3019, 3020, 3021, 3022, 3023, 3024, 3025, 3026, 3027, 3028, 3029, 3030, 3031, 3032, 3033, 3034, 3035, 3036, 3037, 3038, 3039, 3040, 3041, 3042, 3043, 3044, 3045, 3046, 3047, 3048, 3049, 3050, 3051, 3052, 3053, 3054, 3055, 3056, 3057, 3058, 3059, 3060, 3061, 3062, 3063, 3064, 3065, 3066, 3067, 3068, 3069, 3070, 3071, 3072, 3073, 3074, 3075, 3076, 3077, 3078, 3079, 3080, 3081, 3083, 3084, 3085, 3086, 3087, 3088
BE_6L	5, 6, 7, 24, 28, 29, 30, 31, 60, 61, 100, 101, 102, 112, 113, 146, 148, 372, 374, 378, 1000, 1001, 1050, 2020
BE_6M	8, 9, 10, 11, 13, 15, 17, 19, 32, 34, 103, 105, 107, 116, 118, 120, 122, 127, 330, 332, 334, 336, 340, 344, 345, 348, 349, 352, 353, 356, 357, 360, 361, 364, 365, 368, 369, 373
BE_6N	601

Building Designation	Buildings Affected
BE_6O	667
BE_6P	753
BE_6Q	616, 1202, 1203, 1204
BE_6R	900
BE_6S	655
BE_6T	752, 757
BE_6U	667
BE_6V	600, 606, 607, 685
BE_6W	147, 329, 622, 626, 630, 639, 681, 684, 692, 705, 747, 781, 783, 791, 1236, 1330, 1713
BE_7A	62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 128, 130, 132, 219, 221, 223, 225, 227, 229, 231, 233, 235, 237, 239, 241, 243, 245, 247, 252, 254, 256, 258, 260, 262, 264, 266, 268, 270, 272, 274, 276, 278, 280, 282, 284, 286, 288, 290, 292, 294, 296, 298, 397, 399, 401, 403, 405, 407, 409, 411, 413, 415, 417, 419, 423, 425, 427, 429, 431, 433, 1002, 1004, 1006, 1008, 1010
BE_7B	621, 682, 698, 700, 1207, 1403, 1590, 2104, 0705B, 0705C
BE_7C	1, 602, 674, 735
BE_7D	620, 624, 751
BE_7E	727
BE_7F	1231, 500, 613, 623, 717, 806, 1222, 1223, 1225, 2024, 0623A, 0623B, 0673A, 0700A, 0700C, 0746A
BE_7G	745
BE_7H	1, 602, 674, 735
BE_7I	605, 648, 663, 673, 699, 722, 750, 2026
BE_8A	752, 757
BE_8B	62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 128, 130, 132, 219, 221, 223, 225, 227, 229, 231, 233, 235, 237, 239, 241, 243, 245, 247, 252, 254, 256, 258, 260, 262, 264, 266, 268, 270, 272, 274, 276, 278, 280, 282, 284, 286, 288, 290, 292, 294, 296, 298, 397, 399, 401, 403, 405, 407, 409, 411, 413, 415, 417, 419, 423, 425, 427, 429, 431, 433, 1002, 1004, 1006, 1008, 1010
BE_8C	150, 155, 160, 165, 176, 181, 211, 501, 502, 503, 504, 509, 510, 511
BE_8D	845
BE_8E	144, 603, 634, 721
BE_8F	609, 610, 614, 618, 631, 635, 637, 671, 675, 689, 693, 696, 703, 718, 724, 729, 732, 762, 763, 765, 767, 771, 799, 805, 1183, 1230, 1290, 1296, 2018, 2028, 0671A, 0707A
BE_9A	655
BE_9B	2101
BE_9C	753
BE_9D	845
BE_9E	144, 603, 634, 721
BE_9F	600, 606, 607, 685
BE_9G	62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 128, 130, 132, 219, 221, 223, 225, 227, 229, 231, 233, 235, 237, 239, 241, 243, 245, 247, 252, 254, 256, 258, 260, 262, 264, 266, 268, 270, 272, 274, 276, 278, 280, 282, 284, 286, 288, 290, 292, 294, 296, 298, 397, 399, 401, 403, 405, 407, 409, 411, 413, 415, 417, 419, 423, 425, 427, 429, 431, 433, 1002, 1004, 1006, 1008, 1010
BE_9H	150, 155, 160, 165, 176, 181, 211, 501, 502, 503, 504, 509, 510, 511
BE_9I	21, 25, 42, 45, 48, 109, 126, 170, 173, 208, 216, 249
BE_9J	5, 6, 7, 24, 28, 29, 30, 31, 60, 61, 100, 101, 102, 112, 113, 146, 148, 372, 374, 378, 1000, 1001, 1050, 2020

Building Designation	Buildings Affected
BE_9K	525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 585, 587, 1015, 3002, 3003, 3009, 3011, 3012, 3017, 3019, 3020, 3021, 3022, 3023, 3024, 3025, 3026, 3027, 3028, 3029, 3030, 3031, 3032, 3033, 3034, 3035, 3036, 3037, 3038, 3039, 3040, 3041, 3042, 3043, 3044, 3045, 3046, 3047, 3048, 3049, 3050, 3051, 3052, 3053, 3054, 3055, 3056, 3057, 3058, 3059, 3060, 3061, 3062, 3063, 3064, 3065, 3066, 3067, 3068, 3069, 3070, 3071, 3072, 3073, 3074, 3075, 3076, 3077, 3078, 3079, 3080, 3081, 3083, 3084, 3085, 3086, 3087, 3088
BE_9L	8, 9, 10, 11, 13, 15, 17, 19, 32, 34, 103, 105, 107, 116, 118, 120, 122, 127, 330, 332, 334, 336, 340, 344, 345, 348, 349, 352, 353, 356, 357, 360, 361, 364, 365, 368, 369, 373
BE_9M	609, 610, 614, 618, 631, 635, 637, 671, 675, 689, 693, 696, 703, 718, 724, 729, 732, 762, 763, 765, 767, 771, 799, 805, 1183, 1230, 1290, 1296, 2018, 2028, 0671A, 0707A
BE_9N	134, 136, 138, 139, 142, 628, 652, 654, 656, 662, 664
BE_9O	562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 586, 588, 589, 1012

Figure B2. HVAC building designations.

Building Designation	Buildings Affected
HVAC_10A	21, 25, 42, 45, 48, 109, 126, 170, 173, 208, 216, 249
HVAC_10B	40, 114, 421, 422
HVAC_10C	683, 707, 708, 714, 2107, 2110, 0700B
HVAC_10D	134, 136, 138, 139, 142, 628, 652, 654, 656, 662, 664
HVAC_10E	785, 2113
HVAC_10F	605, 648, 663, 673, 699, 722, 750, 2026
HVAC_10G	134, 136, 138, 139, 142, 628, 652, 654, 656, 662, 664
HVAC_10H	1231, 500, 613, 623, 717, 806, 1222, 1223, 1225, 2024, 0623A, 0623B, 0673A, 0700A, 0700C, 0746A
HVAC_10I	621, 682, 698, 700, 1207, 1403, 1590, 2104, 0705B, 0705C
HVAC_10J	147, 329, 622, 626, 630, 639, 681, 684, 692, 705, 747, 781, 783, 791, 1236, 1330, 1713
HVAC_10K	150, 155, 160, 165, 176, 181, 211, 501, 502, 503, 504, 509, 510, 511
HVAC_11A	638, 688, 695, 706, 734, 736, 813, 1238, 1243, 1245, 1247, 1248, 1276, 1338, 1387, 1404, 1438, 1545, 1547, 1561, 1564, 1565, 1569, 1576, 1666, 1670, 1675, 1758, 1848
HVAC_11B	619, 629, 702, 742, 743, 817, 843, 861, 906, 907, 913, 1227, 1232, 1289, 1291, 1292, 1295, 1336, 1351, 1389, 1390, 1397, 1398, 1419, 1421, 1425, 1427, 1428, 1432, 1434, 1548, 1584, 1602, 1625, 1652, 1699, 1712, 1725, 1809, 1815, 1840, 1845, 1851, 1857, 1858, 0695A, 1336A, 1387A
HVAC_11C	646, 665, 670, 687, 719, 733, 793, 795, 901, 1568, 1720
HVAC_11D	646, 665, 670, 687, 719, 733, 793, 795, 901, 1568, 1720
HVAC_11E	646, 665, 670, 687, 719, 733, 793, 795, 901, 1568, 1720
HVAC_11F	710, 604, 672, 690, 713, 715, 716, 726, 728, 731, 761, 797, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 838, 840, 847, 849, 853, 855, 859, 867, 869, 875, 910, 1208, 1210, 1224, 1226, 1244, 1310, 1344, 1349, 1355, 1366, 1379, 1431, 1435, 1532, 1538, 1539, 1542, 1543, 1544, 1551, 1553, 1563, 1599, 1600, 1610, 1622, 1623, 1672, 1715, 1719, 1724, 1841, 1971, 1981, 1982, 0604A, 0604F, 0708A, 1701A, 2110A, INCIN, PUPHS, SUBST, TRTPL
HVAC_12A	300, 301, 302, 303, 304, 306, 307, 309, 310, 311, 312, 313, 314, 315, 316, 515, 3001, 3004, 3005, 3006, 3007, 3008, 3010, 3013, 3015, 3016, 3102, 3104, 3106, 3108, 3110, 3112, 3114, 3120, 3122, 3124, 3126, 3128, 3130, 3132, 3134, 3140, 3142, 3144, 3146, 3148, 3150, 3152, 3154, 3156, 3158, 3160, 3162
HVAC_12B	562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 586, 588, 589, 1012
HVAC_12C	62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 128, 130, 132, 219, 221, 223, 225, 227, 229, 231, 233, 235, 237, 239, 241, 243, 245, 247, 252, 254, 256, 258, 260, 262, 264, 266, 268, 270, 272, 274, 276, 278, 280, 282, 284, 286, 288, 290, 292, 294, 296, 298, 397, 399, 401, 403, 405, 407, 409, 411, 413, 415, 417, 419, 423, 425, 427, 429, 431, 433, 1002, 1004, 1006, 1008, 1010
HVAC_12D	5, 6, 7, 24, 28, 29, 30, 31, 60, 61, 100, 101, 102, 112, 113, 146, 148, 372, 374, 378, 1000, 1001, 1050, 2020

Building Designation	Buildings Affected
HVAC_13A	621, 682, 698, 700, 1207, 1403, 1590, 2104, 0705B, 0705C
HVAC_13B	2101
HVAC_13C	1231, 500, 613, 623, 717, 806, 1222, 1223, 1225, 2024, 0623A, 0623B, 0673A, 0700A, 0700C, 0746A
HVAC_13D	150, 155, 160, 165, 176, 181, 211, 501, 502, 503, 504, 509, 510, 511
HVAC_13E	609, 610, 614, 618, 631, 635, 637, 671, 675, 689, 693, 696, 703, 718, 724, 729, 732, 762, 763, 765, 767, 771, 799, 805, 1183, 1230, 1290, 1296, 2018, 2028, 0671A, 0707A
HVAC_13F	147, 329, 622, 626, 630, 639, 681, 684, 692, 705, 747, 781, 783, 791, 1236, 1330, 1713
HVAC_13G	609, 610, 614, 618, 631, 635, 637, 671, 675, 689, 693, 696, 703, 718, 724, 729, 732, 762, 763, 765, 767, 771, 799, 805, 1183, 1230, 1290, 1296, 2018, 2028, 0671A, 0707A
HVAC_14A	2101
HVAC_14B	1200
HVAC_14C	2101

Figure B3. Lighting building designations.

Building Designation*	Buildings Affected
LI_5A	600, 606, 607, 685
LI_5B	134, 136, 138, 139, 142, 628, 652, 654, 656, 662, 664
LI_5C	134, 136, 138, 139, 142, 628, 652, 654, 656, 662, 664
LI_5D	1556, 1558, 1562, 1580, 1592, 1800
LI_5E	785, 2113
LI_5F	1347, 1353, 1501, 1502, 1503, 1504, 1505, 1506, 1507, 1508, 1509, 1510, 1511, 1512, 1513, 1514, 1515, 1516, 1517, 1518, 1519, 1520, 1521, 1522, 1523, 1524, 1525, 1526, 1611, 1612, 1613, 1614, 1615, 1616, 1617, 1618, 1619, 1620, 1621, 1624, 1703, 1704, 1705, 1706, 1707, 1708, 1709, 1721, 1722, 1723, 1731, 1732, 1734, 1735, T0001, T0002, T0003, T0004, T0005, T0006, T0007, T0008, T0009, T0010
LI_5G	1347, 1353, 1501, 1502, 1503, 1504, 1505, 1506, 1507, 1508, 1509, 1510, 1511, 1512, 1513, 1514, 1515, 1516, 1517, 1518, 1519, 1520, 1521, 1522, 1523, 1524, 1525, 1526, 1611, 1612, 1613, 1614, 1615, 1616, 1617, 1618, 1619, 1620, 1621, 1624, 1703, 1704, 1705, 1706, 1707, 1708, 1709, 1721, 1722, 1723, 1731, 1732, 1734, 1735, T0001, T0002, T0003, T0004, T0005, T0006, T0007, T0008, T0009, T0010
LI_5H	609, 610, 614, 618, 631, 635, 637, 671, 675, 689, 693, 696, 703, 718, 724, 729, 732, 762, 763, 765, 767, 771, 799, 805, 1183, 1230, 1290, 1296, 2018, 2028, 0671A, 0707A
LI_5I	609, 610, 614, 618, 631, 635, 637, 671, 675, 689, 693, 696, 703, 718, 724, 729, 732, 762, 763, 765, 767, 771, 799, 805, 1183, 1230, 1290, 1296, 2018, 2028, 0671A, 0707A
LI_5J	1180, 1181, 1185, 1316, 1328, 1333, 1337, 1341, 1345, 1346, 1348, 1350, 1352, 1354, 1358, 1364, 1391, 1420, 1424, 1439, 1444, 1534, 1550, 1560, 1579, 1604, 1650, 1651, 1655, 1658, 1673, 1683, 1684, 1693, 1702, 1733, 1751, 1753, 1754, 1803, 1804, 1808, 1813, 1827, 1828, 1829, 1842, 1843, 1849, 1864, 1870, 1892, 1893, 1894, 1895, 1902
LI_5K	1180, 1181, 1185, 1316, 1328, 1333, 1337, 1341, 1345, 1346, 1348, 1350, 1352, 1354, 1358, 1364, 1391, 1420, 1424, 1439, 1444, 1534, 1550, 1560, 1579, 1604, 1650, 1651, 1655, 1658, 1673, 1683, 1684, 1693, 1702, 1733, 1751, 1753, 1754, 1803, 1804, 1808, 1813, 1827, 1828, 1829, 1842, 1843, 1849, 1864, 1870, 1892, 1893, 1894, 1895, 1902
LI_5L	683, 707, 708, 714, 2107, 2110, 0700B
LI_5M	600, 606, 607, 685
LI_5N	753
LI_5O	1556, 1558, 1562, 1580, 1592, 1800
LI_5P	40, 114, 421, 422

* Note that some building sets are duplicates. This indicates that there are multiple use areas. 5E and 5F for example might represent Administrative and Maintenance shop areas.

Building Designation*	Buildings Affected
LI_5Q	62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 128, 130, 132, 219, 221, 223, 225, 227, 229, 231, 233, 235, 237, 239, 241, 243, 245, 247, 252, 254, 256, 258, 260, 262, 264, 266, 268, 270, 272, 274, 276, 278, 280, 282, 284, 286, 288, 290, 292, 294, 296, 298, 397, 399, 401, 403, 405, 407, 409, 411, 413, 415, 417, 419, 423, 425, 427, 429, 431, 433, 1002, 1004, 1006, 1008, 1010
LI_5R	150, 155, 160, 165, 176, 181, 211, 501, 502, 503, 504, 509, 510, 511
LI_5S	300, 301, 302, 303, 304, 306, 307, 309, 310, 311, 312, 313, 314, 315, 316, 515, 3001, 3004, 3005, 3006, 3007, 3008, 3010, 3013, 3015, 3016, 3102, 3104, 3106, 3108, 3110, 3112, 3114, 3120, 3122, 3124, 3126, 3128, 3130, 3132, 3134, 3140, 3142, 3144, 3146, 3148, 3150, 3152, 3154, 3156, 3158, 3160, 3162
LI_5T	21, 25, 42, 45, 48, 109, 126, 170, 173, 208, 216, 249
LI_5U	562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 586, 588, 589, 1012
LI_5V	5, 6, 7, 24, 28, 29, 30, 31, 60, 61, 100, 101, 102, 112, 113, 146, 148, 372, 374, 378, 1000, 1001, 1050, 2020
LI_5W	525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 585, 587, 1015, 3002, 3003, 3009, 3011, 3012, 3017, 3019, 3020, 3021, 3022, 3023, 3024, 3025, 3026, 3027, 3028, 3029, 3030, 3031, 3032, 3033, 3034, 3035, 3036, 3037, 3038, 3039, 3040, 3041, 3042, 3043, 3044, 3045, 3046, 3047, 3048, 3049, 3050, 3051, 3052, 3053, 3054, 3055, 3056, 3057, 3058, 3059, 3060, 3061, 3062, 3063, 3064, 3065, 3066, 3067, 3068, 3069, 3070, 3071, 3072, 3073, 3074, 3075, 3076, 3077, 3078, 3079, 3080, 3081, 3083, 3084, 3085, 3086, 3087, 3088
LI_5X	305, 308, 1003, 1005, 1007, 1009, 1011, 1013, 1017, 1019, 1021, 1186
LI_5Y	8, 9, 10, 11, 13, 15, 17, 19, 32, 34, 103, 105, 107, 116, 118, 120, 122, 127, 330, 332, 334, 336, 340, 344, 345, 348, 349, 352, 353, 356, 357, 360, 361, 364, 365, 368, 369, 373
LI_5Z	655
LI_5AA	680, 851, 1240, 1241, 1277, 1278, 1285, 1298, 1315, 1385, 1388, 1393, 1399, 1437, 1546, 1578, 1654, 1656, 1657, 1659, 1660, 1662, 1680, 1681, 1690, 1698, 1710, 1718, 1750, 1768, 1844, 1850, 1868, 1897, 3101, 3103, 3105, 3107, 3109, 3111, 3113, 3115, 3121, 3123, 3125, 3127, 3129, 3131, 3133, 3135, 3141, 3143, 3145, 3147, 3149, 3151, 3153, 3155, 3157, 3159, 3161, 3163, 3165, 3167, 3169, 3171, 3173
LI_5AB	1, 602, 674, 735
LI_5AC	646, 665, 670, 687, 719, 733, 793, 795, 901, 1568, 1720
LI_5AD	752, 757
LI_5AE	616, 1202, 1203, 1204
LI_6A	12, 14, 16, 18, 20, 22, 23, 26, 27, 33, 35, 41, 43, 44, 46, 50, 63, 104, 106, 108, 111, 115, 117, 119, 121, 123, 129, 145, 151, 156, , 333, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 608, 615, 625, 697, 701, 711, 723, 725, 850, 852, 902, 904, 905, 1205, 1294, 1313, 1314, 1317, 1318, 1319, 1320, 1321, 1322, 1323, 1325, 1329, 1334, 1339, 1378, 1396, 1401, 1422, 1423, 1426, 1429, 1433, 1436, 1443, 1445, 1570, 1630, 1661, 1663, 1674, 1677, 1688, 1711, 1760, 1872, 1921, 3101, 3103, 3105, 3107, 3109, 3111, 3113, 3115, 3121, 3123, 3125, 3127, 3129, 3131, 3133, 3135, 3141, 3143, 3145, 3147, 3149, 3151, 3153, 3155, 3157, 3159, 3161, 3163, 3165, 3167, 3169, 3171, 3173, 0060A, 060–1, 0667C, 0667D, 0670A, 0702A, 0706A, 0725A, 0900C, 1207A, 1545A, TPADS
LI_6B	601
LI_6C	745
LI_6D	745
LI_6E	62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 128, 130, 132, 219, 221, 223, 225, 227, 229, 231, 233, 235, 237, 239, 241, 243, 245, 247, 252, 254, 256, 258, 260, 262, 264, 266, 268, 270, 272, 274, 276, 278, 280, 282, 284, 286, 288, 290, 292, 294, 296, 298, 397, 399, 401, 403, 405, 407, 409, 411, 413, 415, 417, 419, 423, 425, 427, 429, 431, 433, 1002, 1004, 1006, 1008, 1010
LI_6F	150, 155, 160, 165, 176, 181, 211, 501, 502, 503, 504, 509, 510, 511
LI_6G	562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 586, 588, 589, 1012
LI_6H	5, 6, 7, 24, 28, 29, 30, 31, 60, 61, 100, 101, 102, 112, 113, 146, 148, 372, 374, 378, 1000, 1001, 1050, 2020
LI_6I	8, 9, 10, 11, 13, 15, 17, 19, 32, 34, 103, 105, 107, 116, 118, 120, 122, 127, 330, 332, 334, 336, 340, 344, 345, 348, 349, 352, 353, 356, 357, 360, 361, 364, 365, 368, 369, 373

Building Designation*	Buildings Affected
LI_6J	710, 604, 672, 690, 713, 715, 716, 726, 728, 731, 761, 797, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 838, 840, 847, 849, 853, 855, 859, 867, 869, 875, 910, 1208, 1210, 1224, 1226, 1244, 1310, 1344, 1349, 1355, 1366, 1379, 1431, 1435, 1532, 1538, 1539, 1542, 1543, 1544, 1551, 1553, 1563, 1599, 1600, 1610, 1622, 1623, 1672, 1715, 1719, 1724, 1841, 1971, 1981, 1982, 0604A, 0604F, 0708A, 1701A, 2110A, INCIN, PUPHS, SUBST, TRTPL
LI_6K	646, 665, 670, 687, 719, 733, 793, 795, 901, 1568, 1720
LI_6L	1200
LI_6M	616, 1202, 1203, 1204
LI_6N	727
LI_6O	655
LI_6P	605, 648, 663, 673, 699, 722, 750, 2026
LI_6Q	1231, 500, 613, 623, 717, 806, 1222, 1223, 1225, 2024, 0623A, 0623B, 0673A, 0700A, 0700C, 0746A
LI_6R	785, 2113
LI_6S	1347, 1353, 1501, 1502, 1503, 1504, 1505, 1506, 1507, 1508, 1509, 1510, 1511, 1512, 1513, 1514, 1515, 1516, 1517, 1518, 1519, 1520, 1521, 1522, 1523, 1524, 1525, 1526, 1611, 1612, 1613, 1614, 1615, 1616, 1617, 1618, 1619, 1620, 1621, 1624, 1703, 1704, 1705, 1706, 1707, 1708, 1709, 1721, 1722, 1723, 1731, 1732, 1734, 1735, T0001, T0002, T0003, T0004, T0005, T0006, T0007, T0008, T0009, T0010
LI_6T	621, 682, 698, 700, 1207, 1403, 1590, 2104, 0705B, 0705C
LI_6U	147, 329, 622, 626, 630, 639, 681, 684, 692, 705, 747, 781, 783, 791, 1236, 1330, 1713
LI_6V	2101
LI_6W	2101
LI_6X	753
LI_6Y	900
LI_6Z	900
LI_6AA	752, 757
LI_6AB	667
LI_6AC	667
LI_6AD	600, 606, 607, 685
LI_6AE	745
LI_6AF	738, 740, 756
LI_6AG	845
LI_6AH	144, 603, 634, 721
LI_6AI	1400, 1575, 1585, 1701, 1714, 1736
LI_6AJ	727
LI_6AK	683, 707, 708, 714, 2107, 2110, 0700B
LI_7A	646, 665, 670, 687, 719, 733, 793, 795, 901, 1568, 1720
LI_7B	616, 1202, 1203, 1204
LI_7C	727
LI_7D	601
LI_7E	2101
LI_7F	2101
LI_7G	1200
LI_7H	727
LI_7I	683, 707, 708, 714, 2107, 2110, 0700B
LI_7J	601
LI_7K	667
LI_7L	600, 606, 607, 685

Building Designation*	Buildings Affected
LI_7M	753
LI_7N	616, 1202, 1203, 1204
LI_8A	646, 665, 670, 687, 719, 733, 793, 795, 901, 1568, 1720
LI_8B	727
LI_8C	727
LI_8D	745
LI_9A	900
LI_9B	900
LI_9C	62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 128, 130, 132, 219, 221, 223, 225, 227, 229, 231, 233, 235, 237, 239, 241, 243, 245, 247, 252, 254, 256, 258, 260, 262, 264, 266, 268, 270, 272, 274, 276, 278, 280, 282, 284, 286, 288, 290, 292, 294, 296, 298, 397, 399, 401, 403, 405, 407, 409, 411, 413, 415, 417, 419, 423, 425, 427, 429, 431, 433, 1002, 1004, 1006, 1008, 1010
LI_9D	150, 155, 160, 165, 176, 181, 211, 501, 502, 503, 504, 509, 510, 511
LI_9E	300, 301, 302, 303, 304, 306, 307, 309, 310, 311, 312, 313, 314, 315, 316, 515, 3001, 3004, 3005, 3006, 3007, 3008, 3010, 3013, 3015, 3016, 3102, 3104, 3106, 3108, 3110, 3112, 3114, 3120, 3122, 3124, 3126, 3128, 3130, 3132, 3134, 3140, 3142, 3144, 3146, 3148, 3150, 3152, 3154, 3156, 3158, 3160, 3162
LI_9F	21, 25, 42, 45, 48, 109, 126, 170, 173, 208, 216, 249
LI_9G	562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 586, 588, 589, 1012
LI_9H	5, 6, 7, 24, 28, 29, 30, 31, 60, 61, 100, 101, 102, 112, 113, 146, 148, 372, 374, 378, 1000, 1001, 1050, 2020
LI_9I	525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 585, 587, 1015, 3002, 3003, 3009, 3011, 3012, 3017, 3019, 3020, 3021, 3022, 3023, 3024, 3025, 3026, 3027, 3028, 3029, 3030, 3031, 3032, 3033, 3034, 3035, 3036, 3037, 3038, 3039, 3040, 3041, 3042, 3043, 3044, 3045, 3046, 3047, 3048, 3049, 3050, 3051, 3052, 3053, 3054, 3055, 3056, 3057, 3058, 3059, 3060, 3061, 3062, 3063, 3064, 3065, 3066, 3067, 3068, 3069, 3070, 3071, 3072, 3073, 3074, 3075, 3076, 3077, 3078, 3079, 3080, 3081, 3083, 3084, 3085, 3086, 3087, 3088
LI_9J	305, 308, 1003, 1005, 1007, 1009, 1011, 1013, 1017, 1019, 1021, 1186
LI_9K	8, 9, 10, 11, 13, 15, 17, 19, 32, 34, 103, 105, 107, 116, 118, 120, 122, 127, 330, 332, 334, 336, 340, 344, 345, 348, 349, 352, 353, 356, 357, 360, 361, 364, 365, 368, 369, 373
LI_9L	147, 329, 622, 626, 630, 639, 681, 684, 692, 705, 747, 781, 783, 791, 1236, 1330, 1713
LI_9M	845
LI_9N	144, 603, 634, 721
LI_10A	616, 1202, 1203, 1204
LI_10B	1200

Figure B4. Hot water building designations.

Building Designation	Buildings Affected
SHW_1A	683, 707, 708, 714, 2107, 2110, 0700B
SHW_1B	2101
SHW_1C	616, 1202, 1203, 1204
SHW_1D	683, 707, 708, 714, 2107, 2110, 0700B
SHW_1E	147, 329, 622, 626, 630, 639, 681, 684, 692, 705, 747, 781, 783, 791, 1236, 1330, 1713
SHW_1F	1556, 1558, 1562, 1580, 1592, 1800
SHW_1G	785, 2113
SHW_1H	144, 603, 634, 721
SHW_1I	134, 136, 138, 139, 142, 628, 652, 654, 656, 662, 664
SHW_1J	134, 136, 138, 139, 142, 628, 652, 654, 656, 662, 664

Building Designation	Buildings Affected
SHW_1K	621, 682, 698, 700, 1207, 1403, 1590, 2104, 0705B, 0705C
SHW_1L	1400, 1575, 1585, 1701, 1714, 1736
SHW_2A	900
SHW_2B	646, 665, 670, 687, 719, 733, 793, 795, 901, 1568, 1720
SHW_2C	845
SHW_2D	2101
SHW_2E	1200
SHW_2F	147, 329, 622, 626, 630, 639, 681, 684, 692, 705, 747, 781, 783, 791, 1236, 1330, 1713
SHW_2G	147, 329, 622, 626, 630, 639, 681, 684, 692, 705, 747, 781, 783, 791, 1236, 1330, 1713
SHW_2H	147, 329, 622, 626, 630, 639, 681, 684, 692, 705, 747, 781, 783, 791, 1236, 1330, 1713
SHW_2I	605, 648, 663, 673, 699, 722, 750, 2026
SHW_2J	667
SHW_2K	667
SHW_2L	710, 604, 672, 690, 713, 715, 716, 726, 728, 731, 761, 797, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 838, 840, 847, 849, 853, 855, 859, 867, 869, 875, 910, 1208, 1210, 1224, 1226, 1244, 1310, 1344, 1349, 1355, 1366, 1379, 1431, 1435, 1532, 1538, 1539, 1542, 1543, 1544, 1551, 1553, 1563, 1599, 1600, 1610, 1622, 1623, 1672, 1715, 1719, 1724, 1841, 1971, 1981, 1982, 0604A, 0604F, 0708A, 1701A, 2110A, INCIN, PUPHS, SUBST, TRTPL
SHW_2M	609, 610, 614, 618, 631, 635, 637, 671, 675, 689, 693, 696, 703, 718, 724, 729, 732, 762, 763, 765, 767, 771, 799, 805, 1183, 1230, 1290, 1296, 2018, 2028, 0671A, 0707A
SHW_2N	1180, 1181, 1185, 1316, 1328, 1333, 1337, 1341, 1345, 1346, 1348, 1350, 1352, 1354, 1358, 1364, 1391, 1420, 1424, 1439, 1444, 1534, 1550, 1560, 1579, 1604, 1650, 1651, 1655, 1658, 1673, 1683, 1684, 1693, 1702, 1733, 1751, 1753, 1754, 1803, 1804, 1808, 1813, 1827, 1828, 1829, 1842, 1843, 1849, 1864, 1870, 1892, 1893, 1894, 1895, 1902
SHW_2O	605, 648, 663, 673, 699, 722, 750, 2026
SHW_2P	40, 114, 421, 422
SHW_2Q	62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 128, 130, 132, 219, 221, 223, 225, 227, 229, 231, 233, 235, 237, 239, 241, 243, 245, 247, 252, 254, 256, 258, 260, 262, 264, 266, 268, 270, 272, 274, 276, 278, 280, 282, 284, 286, 288, 290, 292, 294, 296, 298, 397, 399, 401, 403, 405, 407, 409, 411, 413, 415, 417, 419, 423, 425, 427, 429, 431, 433, 1002, 1004, 1006, 1008, 1010
SHW_2R	150, 155, 160, 165, 176, 181, 211, 501, 502, 503, 504, 509, 510, 511
SHW_2S	21, 25, 42, 45, 48, 109, 126, 170, 173, 208, 216, 249
SHW_2T	5, 6, 7, 24, 28, 29, 30, 31, 60, 61, 100, 101, 102, 112, 113, 146, 148, 372, 374, 378, 1000, 1001, 1050, 2020
SHW_2U	8, 9, 10, 11, 13, 15, 17, 19, 32, 34, 103, 105, 107, 116, 118, 120, 122, 127, 330, 332, 334, 336, 340, 344, 345, 348, 349, 352, 353, 356, 357, 360, 361, 364, 365, 368, 369, 373
SHW_2V	21, 25, 42, 45, 48, 109, 126, 170, 173, 208, 216, 249
SHW_2W	300, 301, 302, 303, 304, 306, 307, 309, 310, 311, 312, 313, 314, 315, 316, 515, 3001, 3004, 3005, 3006, 3007, 3008, 3010, 3013, 3015, 3016, 3102, 3104, 3106, 3108, 3110, 3112, 3114, 3120, 3122, 3124, 3126, 3128, 3130, 3132, 3134, 3140, 3142, 3144, 3146, 3148, 3150, 3152, 3154, 3156, 3158, 3160, 3162
SHW_2X	562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 586, 588, 589, 1012
SHW_2Y	525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 585, 587, 1015, 3002, 3003, 3009, 3011, 3012, 3017, 3019, 3020, 3021, 3022, 3023, 3024, 3025, 3026, 3027, 3028, 3029, 3030, 3031, 3032, 3033, 3034, 3035, 3036, 3037, 3038, 3039, 3040, 3041, 3042, 3043, 3044, 3045, 3046, 3047, 3048, 3049, 3050, 3051, 3052, 3053, 3054, 3055, 3056, 3057, 3058, 3059, 3060, 3061, 3062, 3063, 3064, 3065, 3066, 3067, 3068, 3069, 3070, 3071, 3072, 3073, 3074, 3075, 3076, 3077, 3078, 3079, 3080, 3081, 3083, 3084, 3085, 3086, 3087, 3088
SHW_2Z	305, 308, 1003, 1005, 1007, 1009, 1011, 1013, 1017, 1019, 1021, 1186

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14. ABSTRACT

An Energy Optimization Assessment was conducted at West Point, NY, as a part of the International Energy Agency (IEA) Energy Conservation in Buildings and Community Systems (ECBCS) initiative to identify energy inefficiencies and wastes and propose energy-related projects with applicable funding and execution methods that could enable the installation to better meet the energy reduction requirements mandated by Executive Order 13123 and Energy Policy Act (EPAct) 2005. The study was conducted by the Energy Team, composed of the Construction Engineering Research Laboratory (ERDC-CERL) researchers and their subject matter experts, and the Pacific Northwest National Laboratory (PNNL). The scope of the Annex 46 Energy Optimization Assessment included a Level I study of the central energy plants and associated steam distribution systems providing heat to representative administrative buildings, laundry, dining facilities and other buildings and an analysis of their building envelopes, ventilation air systems, and lighting. The study identified 263 different energy conservation measures (ECMs) that would reduce West Point's annual energy use by up to 225,000 MMBtu/yr, or 25 percent. Most of the proposed energy conservation measures were quantified economically. These ECMs are presented in eight packages with recommendations on their implementation strategies.

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